THE BULLETIN

OF THE

AMERICAN CERAMIC SOCIETY

Volume 19 OCTOBER, 1940 Number 10

EUGENE CORNELIUS SULLIVAN

For story, see page 378

You don't KNOW the game until

YOU'VE PLAYED IT

There's more to ceramic colors than you can find in a book, too.

A handbook may tell you the technique of getting from one end of the field to the other—but you never really *know* how it's done until you've done a bit of broken field running yourself.

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The technologists in our laboratory realize the importance of constant research, and make use of every scientific means to find facts about Drakenfeld colors and chemicals that will make your production easier, more economical.

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We've been playing the game for over seventy-one years, and though we always keep our laboratory eye on the future, you'll find that the rich experience we've gained in the past will be equally helpful to you in ironing out your production problems.

When we say, then, that Drakenfeld technologists will be glad to help you without obligation, we also mean that they'll be able to give you latest laboratory findings—plus the practical knowledge that comes of long experience. Why not drop us a note the next time you run into a production problem that looks like a tough one?

* * *

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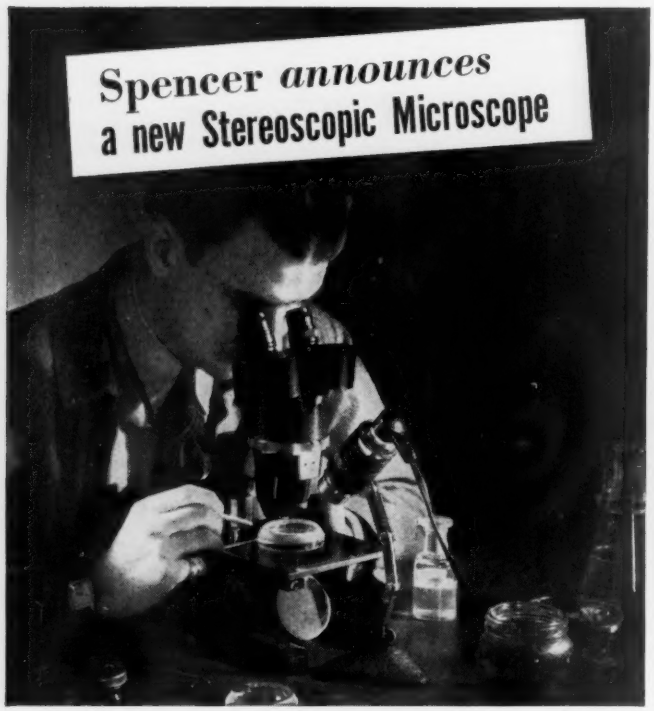

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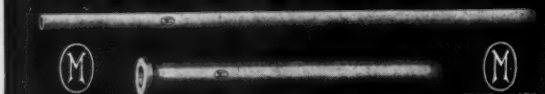

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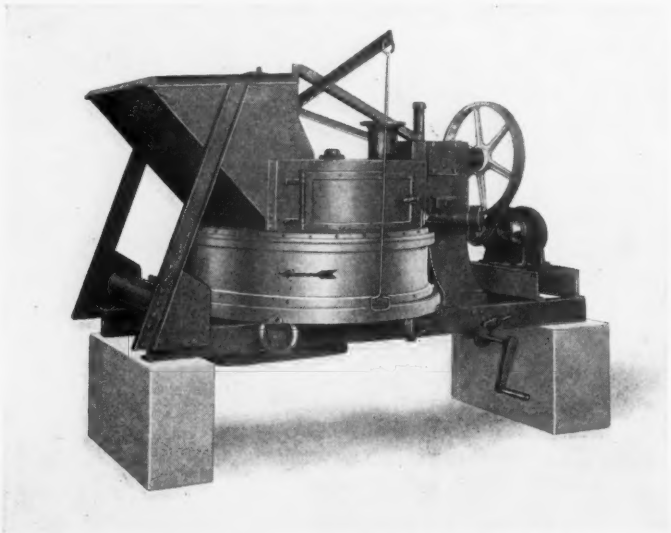

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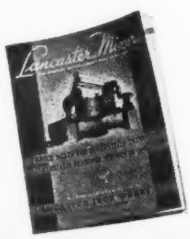

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—o—

Five Fellowship appointments have been made by the Edward Orton, Jr., Ceramic Foundation for 1940–1941.

The Ohio State University: CHARLES B. TAUBER, "Influence of Kiln Atmosphere on Whiteware Fluxes."

The University of Illinois: H. C. THOMPSON, "Glaze Slip Control" (continuation).

The Pennsylvania State College: LANE MITCHELL, "Mineralogical and Colloidal Constitution of Certain Clay Types."

The New York State College of Ceramics: EVERETT THOMAS, "Effect of Glaze Penetration on Resistance of Porous Bodies to Crazing and Shivering."

Rutgers University: WILLIAM L. PESKIN, "Effect of Atmosphere on Qualities of Colors Produced in Colored Glazes of Several Types."

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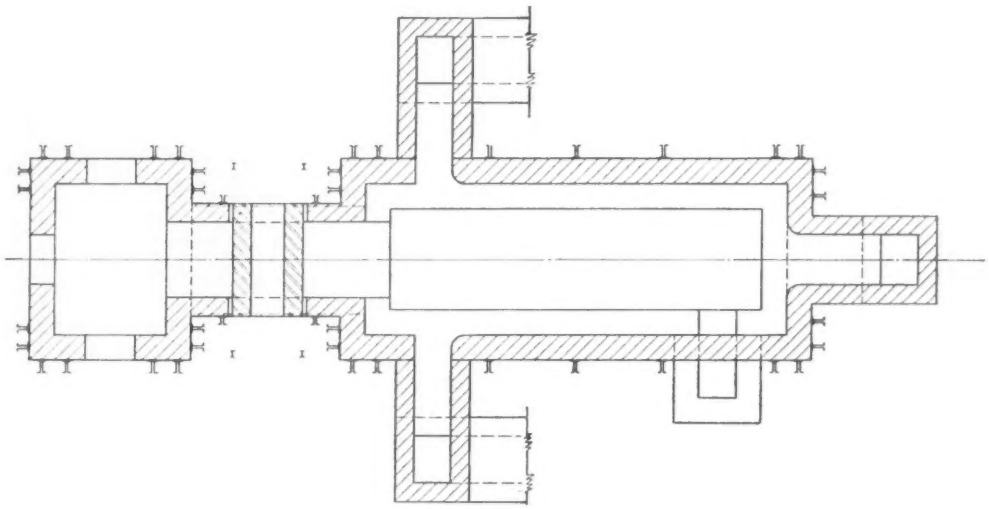

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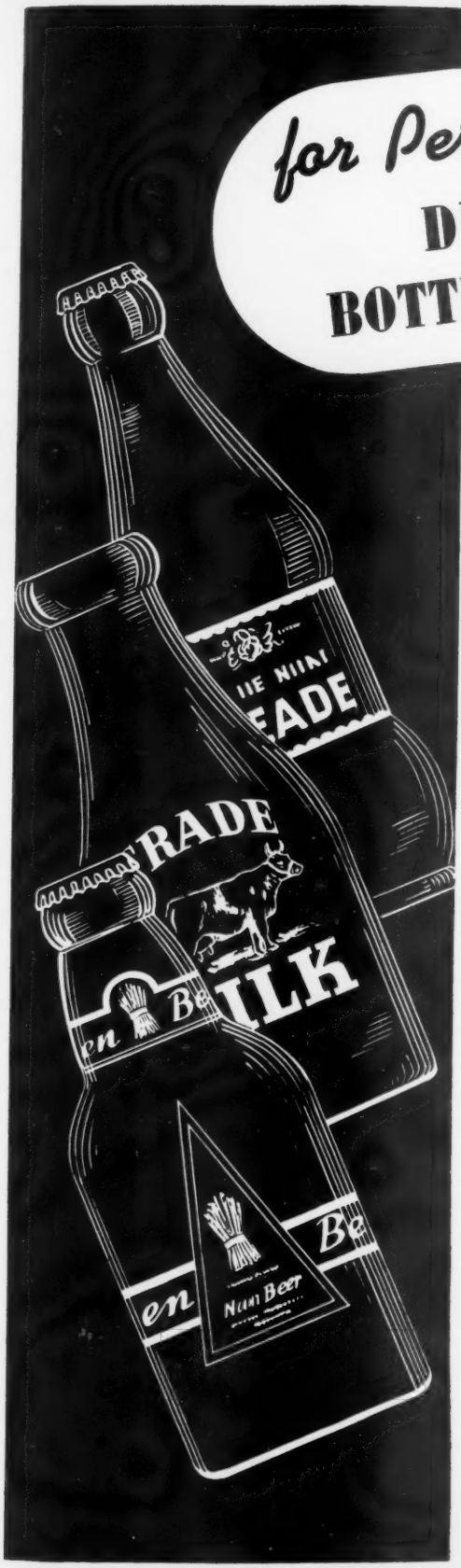

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CORHART* STANDARD ELECTROCAST HELPS TO SET A NEW HIGH RECORD!

MOST glass men, we feel sure, will be interested in the record of a clear flint bottle glass furnace which was recently shut down for complete repairs after producing 65,011 tons of glass during a total life of 833 producing days—within our knowledge *a new high record of 128.9 tons of glass at the feeders, for each square foot of melting area.*

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Fire placed in tank	October 4, 1937
Production started	October 18, 1937
Production off—fires out	February 27, 1939
Fires placed back in tank	March 2, 1939
Production on	March 7, 1939
Production off—fires out	March 11, 1940
Melting end area	504 Square feet

Total days life	884
Operating days	833
Days heating up	17
Idle days	34

Total tons glass produced	65,011
Tons glass produced per operating day	78.0
Sq. ft. melting area per ton glass per operating day	6.46
Average pack	90%
Cause of shut down	Ports
Tons per sq. ft. melting area per life	128.9

Note: When this tank was rebuilt, Corhart* Standard Electrocast was used in breastwalls and ports.

This, you will agree is a rather spectacular record. Yet it has been closely approached by several Corhart tanks in the past, and will unquestionably be exceeded by many such tanks in the future. For the glass industry is moving forward more rapidly today than ever before, and the records of 1940 are unquestionably the commonplace performances of tomorrow. . . .

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PAPERS

RELATION OF SETTING FACE BRICK IN DOWNDRAFT KILNS TO HEAT DISTRIBUTION*

By Frank E. Lobaugh

Abstract

Various types of settings for face brick in downdraft kilns which burn coal under induced draft are discussed. It is important not only to get the hot gases to the bottom of the kiln but to hold them there for a sufficient length of time so that the heat can be absorbed by the ware. Tight setting in the bottom courses aids considerably in obtaining this condition.

I. Introduction

It is the endeavor of every kiln fireman to so operate his kilns that all of the brick are salable. To obtain this result, it is necessary to have all of the brick throughout the kiln fired to a sufficient degree of hardness. The most difficult section in which to produce hard-fired brick in downdraft kilns is in the bottom courses of the setting.

II. Factors Which Govern Firing

Many factors must be considered in firing a downdraft kiln set with brick. Among these are (1) the type of kiln with its flue arrangement, (2) the kind of fuel, (3) the intensity of draft, (4) the height of the stack or the capacity of the exhaust fan, (5) the physical and chemical properties of the clay used in the manufacture of the ware, (6) the kind of ware, (7) its method of fabrication, and (8) the manner in which the ware is set in the kiln.

The kiln bottom should be of such a design that the floor openings and flues are sufficiently large to carry away all of the moisture formed during the water-smoking period yet small enough to offer sufficient resistance during the later periods of the firing so that the heat in the bottom courses of the setting is not carried out by the pull of the stack or fan before it has done its useful work.

Forced, induced, or natural draft may be used in firing with coal. In forced-draft firing with any type of fuel, a pressure greater than atmospheric may be established in the ashpit, whereas with induced or natural draft the air pressure in the ashpit is less than that of the atmosphere. The type of fuel and also the kind of draft affect the amount of pressure in the kiln crown as well as throughout the kiln.

The size of the stack should be based on the work required of it, namely, a cross section sufficient to carry off all of the moisture as rapidly as it is formed during the water-smoking period and sufficient height to produce the draft required to burn the amount of fuel necessary to reach a definite temperature within a given length of time. If an exhaust fan is used for induced draft, it should be of sufficient capacity to accomplish the same requirements as the stack.

The characteristics of the clay or its physical and chemical properties, unfortunately, determine many factors. If the clay has a short vitrification range, the temperature in the crown of the kiln must be held to a definite limit until the bottom courses of the setting have attained a required temperature in order to prevent overfiring the top courses of brick. If the clay has a low dry strength, the setting must be such that the brick do not become bats. Dense clays require longer periods to water smoke and oxidize than do the more open clays. Clays with a high shrinkage must be fired with more care than those of low shrinkage so that the benches of brick will not roll.

The method of fabrication is also an important factor. Ware made either by the dry-press or the soft-

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 10, 1940 (Structural Clay Products Division). Received April 10, 1940.

mud process is more porous than that made of stiff mud and will water smoke and oxidize much faster. Deaired clay, made by any of the processes named, will be more dense than the undeaired clay made by the same process.

All of these factors are predetermined, and the only change that the kiln fireman could reasonably make would be an alteration in setting. Because the manner in which the ware is set in the kiln determines to a large degree the heat distribution throughout the kiln, it is one of the most important factors. Heat distribution is governed by draft, and uniform heat distribution requires uniform draft throughout the kiln.

III. Heat Distribution

The theory of draft will not be discussed here, but a knowledge of the performance of the gases when they enter the kiln is important. If the outside air is assumed to be 70°F., 1 cu. ft. of this air at 300°F. becomes $1 \times 760/530$ or 1.4 cu. ft. Because the hottest section of the kiln at the start of the firing is just above the bag walls, the expansion of the hot gases causes a slight pressure which is exerted in all directions. Most of these gases go to the crown, but a portion is forced into the setting, especially that part which is set as headers facing the bag walls. The movement of the latter gases through the setting is first horizontal and then vertical, down through the setting. Because face brick are usually set face to face and then in alternate headers and stretchers, a series of individual chimneys are set up which take care of the vertical draft. These hot gases do not penetrate very far horizontally (at the earlier stages of the firing) before they are drawn down through the vertical chimneys. As the firing is increased, the hot gases expand more. At 600°F., the 1 cu. ft. of outside air becomes 2 cu. ft.; at 1000°F., 2.7 cu. ft.; at 1500°F., 3.7 cu. ft.; and at 2000°F., 4.6 cu. ft. As the volume of the hot gases increases, an increase in pressure occurs, and some of the hot gases penetrate deeper horizontally into the setting before the downward vertical movement is started. As the firing proceeds, the hottest area may be somewhat higher than that of the top of the bag wall, depending on the amount of secondary air admitted and whether any combustion is taking place in the kiln. The hottest section in the kiln, under these conditions, may be in the crown, and the greatest expansion and therefore the greatest pressure would also be in the crown. There is expansion, however, and therefore pressure is exerted all the way from the top of the bag wall to the crown of the kiln.

The natural tendency of the gases is to reach the crown of the kiln, and if the brick are set too high or too close to the crown, the gases are baffled. The hottest section then is at the baffle, and the greatest expansion and pressure are also in that area. It is more difficult in this case for the gases to reach the center of the kiln and the bottom of the setting. This usually results in overfired tops and underfired bottoms. The best results are obtained when there is no obstruction to the gases before they reach the kiln crown. When they are at the crown, however, the pressure is uniformly distributed over the whole top surface of the setting and down through the setting.

Investigations some years ago by the U. S. Bureau of Mines[1] on four kilns firing refractory brick showed that the positive pressure in the crowns of these kilns averaged about 0.08 in. of water; the top of wicket, 0.02 in.; and the bottom of wicket, a negative pressure of 0.03 in. of water. The pressures were those for air at the same level. Their curves also showed that a rise or fall in the pressure at the crown likewise affected a corresponding rise or fall in pressure at the top and bottom of wicket.

The positive pressure is a result of the expanded gases, whereas the negative pressure is caused by the pull of the stack. A neutral area therefore exists at some point between the top and bottom of wicket where there is neither positive nor negative pressure. The lower this neutral point is obtained in the kiln, the greater will be the degree of heat in the bottom courses of the setting.

The first sections of the ware to receive heat are those near the bag wall. This is desirable because if all the heat should go to the crown and then be drawn vertically through the setting all of the moisture formed during the water-smoking period in the top courses of the ware would have to be drawn down through the entire setting. This would cause condensation and absorption of the moisture by the cooler ware in the lower courses, unless there was sufficient draft and volume of air to prevent this condensation. Some plants remove all of the portholes in the crown during the water-smoking period so that a considerable amount of the moisture from the top courses of the ware goes out through the crown and not through the entire setting.

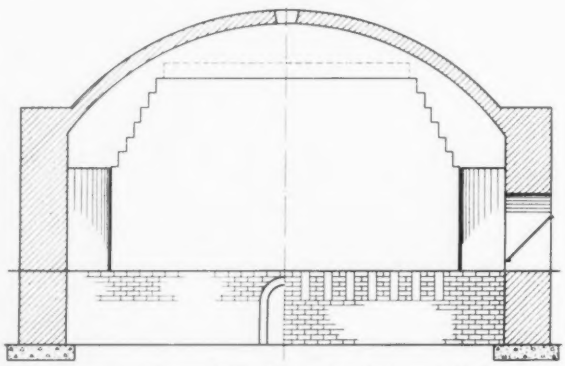

FIG. 1.—Downdraft kiln using induced draft.

As the kiln becomes hotter and the pressure in the crown increases, the hot gases are gradually forced down through the setting. The center section in the bottom is the last portion of the kiln to become red. It is often difficult to get the hot gases to flow into this section. Usually one or two flash fires will start the flow of gases in sluggish sections of the setting.

[1] R. A. Sherman, R. F. Lunger, and W. E. Rice, "Significance of Drafts in Downdraft Coal-Fired Kilns," *Jour. Amer. Ceram. Soc.*, **7** [4] 255–70 (1924).

When the entire setting is red throughout, it is important that the temperature be as nearly uniform as possible throughout the kiln. Fast firing during either the water-smoking or the oxidizing periods will cause a temperature considerably higher in the top than in the bottom courses of the ware. It is necessary during these periods to have the damper open in the stack to carry away the moisture and also to have large volumes of hot gases passing through the ware to water smoke and oxidize the clay. Following the oxidation period, the damper is placed in the stack to hold back some of the hot gases and to soak the ware until the kiln is finished. When the stack is at a distance from the kiln, the place where the gases are the most retarded is at the damper. The place to damper a kiln to obtain the best results is as near the bottom of the setting as possible. In fact, by setting the ware closer in the bottom courses, the kiln is being dampered in this section. It is important not only to get the hot gases to the bottom courses but to hold them there for a sufficient length of time so that the heat may be absorbed by the ware.

In discussing heat distribution, Lovejoy[2] says,

> This brings us to the kiln-floor problem upon which largely depends successful firing, distribution of heat throughout the kiln chamber, and uniformity of fired product. Suppose we tighten the kiln floor and thus increase the resistance to the passage of the gas. It would seem to follow that the gas would cease to flow, but such is not the case. The flow continues but at a slower rate, and with reduced velocity, the friction is reduced in greater degree. The friction of gases in flues may vary as the square of the velocity. If, in the first instance, we represent the velocity as two, the friction will be four. If, in the second instance, we reduce the friction of the gases in the flues, this varies as the square of the velocity. Reduce the velocity to one, the friction becomes one. With the velocity reduced to one half, we reduce the friction to one quarter. We thus make a decided gain in available pressure to spread the gases to all parts of the kiln above the floor. The slower movement throughout the system reduces the friction in every part of the system—grates, bags, ware, floor, flues, and stack—and gives us higher available pressure in the kiln chamber.
>
> Besides the spreading of the gases to all parts of the kiln, especially important in the lower part of the kiln, we further gain in actual heat in consequence of any increase in the pressure. Pressure applied to gases converts latent heat into sensible heat and vice versa. The slower movement of the hot gases gives more time for the absorption of the heat by the ware and its conduction into the ware.

IV. Setting

A system of setting brick which would be ideal (if this were possible) would be one that is open during the water-smoking period and tight during the soaking period. The type of setting unfortunately is controlled by the properties of the clay used in the manufacture of the ware, but in working out a system of setting, it is the period of the firing that is most important for the particular clay chosen. If the clay is dense, plastic, and water smokes and oxidizes with difficulty, the setting should be open, but if it is close, additional time must be allowed to take the ware safely through these periods.

In a chapter on setting downdraft kilns, Greaves-Walker[3] says,

> The floor runner brick should be set to conform to the type of bottom. In solid-bottom, center-well round kilns, they should be set radially for, if set across the kiln with openings between for draft passage, the draft will short cut to the center, taking the path of least resistance. In checker- or riddle-bottom kilns, the runners should be set so as not to interfere with the floor openings. Many kilns work badly for no other reason than that no attention is paid by the setters to the openings in the floor. Setters should always be impressed with this fact and should be compelled to avoid setting brick over the openings.
>
> When the gases short cut from the fireboxes into the flues and leave a cone of soft brick in the center, the setting should be tight near the bag walls and gradually loosened as the middle of the kiln is approached. The effect of this is to baffle the gases near the fireboxes and drive them toward the center—they naturally follow the path of least resistance.

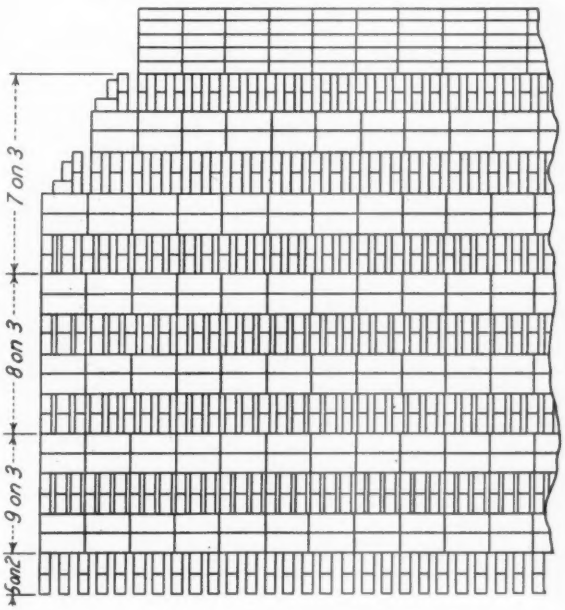

FIG. 2.—Combination setting.

The general practice in face-brick plants is to set the entire kiln with one type of setting, such as 5 on 2, 7 on 3, etc. Various types of settings were tried on a plant burning coal in downdraft kilns under induced draft. The general practice in this plant was to set the whole

[2] Ellis Lovejoy, Fundamentals and Economies in the Clay Industries, p. 240. Randall Publishing Co., Wellsville, N. Y., 1935; *Ceram. Abs.*, **14** [9] 236 (1935).

[3] A. F. Greaves-Walker, Clay Plant Construction and Operation, p. 65. Brick and Clay Record, Chicago, Ill., 1919.

kiln 5 on 2, except for the center bench which was set 4 on 2. The purpose of the more open setting in the center was to draw more heat to that section where it had been difficult to fire the brick hard. The brick in the bottom courses were not fired sufficiently hard for face brick with this type of setting.

On the theory that brick set tightly in the bottom courses and more open in the top courses would give a better heat distribution, one kiln was set as follows: bottom two courses, set 5 on 2; next six courses, 6 on 2; next eight courses, equivalent to 8 on 3; next ten courses, equivalent to 7 on 3; and five courses, flat on top for black faces (Fig. 2). It was suggested that a more open setting of 5 on 2 in the bottom two courses would aid in water smoking. The kiln was fired satisfactorily, but the open setting in the top courses cut down considerably the number of brick set in the kiln.

An entire kiln was next set 3 on 1. Although satisfactory results were obtained, it was necessary to prolong the water-smoking and oxidizing periods.

A third kiln was set with the six bottom courses 3 on 1 except for the center bench, which was set 5 on 2; the remaining 24 courses were set 5 on 2. With the tighter setting in the bottom courses, a most satisfactory firing resulted. All of the brick in the kiln, including the course on the kiln floor, were fired to a sufficient degree of hardness to ship as face brick. Repeated tests were made of this type of setting, and after identical results were obtained in a number of kilns, this system was adopted in the plant for all edge-set brick.

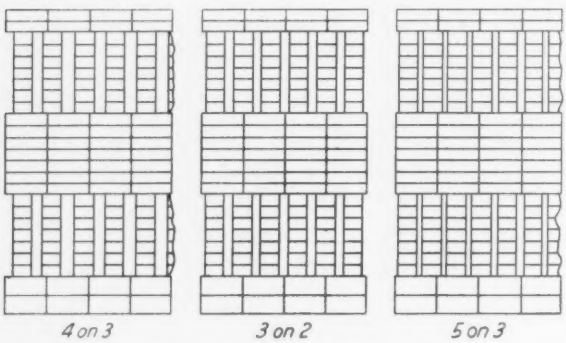

FIG. 3.—Flat-set brick.

The next problem was to find a satisfactory system for flat-set brick. Using the same theory, that of tight setting in the bottom to give a better heat distribution throughout the kiln, it was decided that six courses of brick should be set 3 on 1, face to face, and the flat setting started from the sixth course. The flat setting in the first kiln was 4 on 3, in the second kiln 3 on 2, and in the third kiln 5 on 3 (Fig. 3). Each of these types of setting gave good results, and the 5-on-3 system was adopted because of the increased capacity of the kiln. The course of brick on the kiln floor could be flashed with this type of setting to such a degree as to produce red hearts.

The foregoing methods were used to set the round kilns. In the rectangular kilns, there was a tendency for the sections near the bag walls to fire the brick harder than in other sections of the kiln. A system of tier setting (Fig. 4) was found to give excellent results. A four-brick bench, with four courses of brick set face to face, 3 on 1, was set adjacent the bag walls. The flat-set brick were started from the fourth course and set 7 on 4. The center bench was started with two courses set face to face, 5 on 2, then two courses set the same way, 3 on 1. The flat setting was started from the fourth course and set forty-one courses high, 5 on 3.

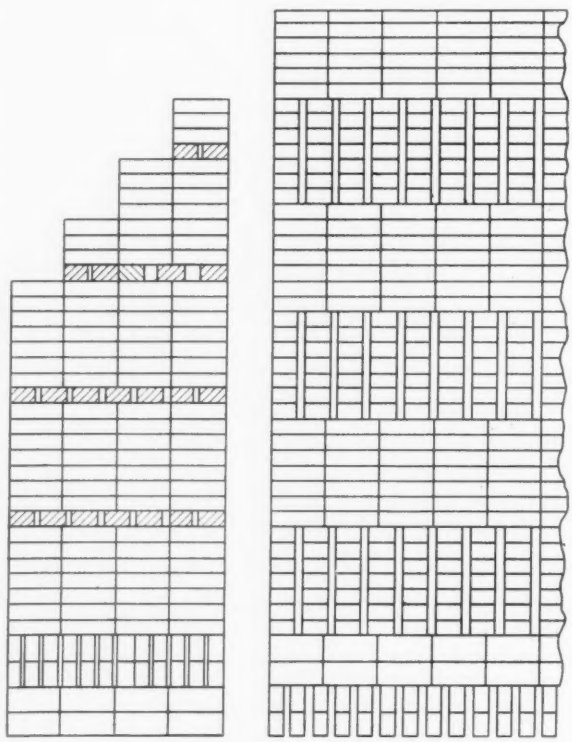

FIG. 4.—Flat setting in rectangular kiln.

V. Summary

Heat distribution in a downdraft kiln may be controlled by the proper method of setting brick in the kiln. Tight setting in the bottom courses decreases the velocity of the gases in that section, thus lowering the neutral point of draft and giving a more uniform distribution of heat throughout the kiln.

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NEW YORK STATE COLLEGE OF CERAMICS
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PHYSICAL CHEMISTRY OF GAS-PRODUCER REACTIONS IN RELATION TO CERAMIC FIRING*

By A. W. Gauger

Abstract

Air-blown producer-gas reactions occur in the firing of any thick, solid fuel bed. These consist of the following fundamental reactions:

$$\underbrace{C + O_2 + 3.76N_2}_{\text{Air}} = CO_2 + 3.76N_2$$

$$CO_2 + 3.76N_2 + C = \underbrace{2CO + 3.76N_2}_{\text{Producer gas}}$$

The producer gas thus formed ordinarily is burned at the top of the fuel bed upon admission of secondary air. This, however, need not necessarily be the case. The earliest developments in producer-gas art, in fact, were along the lines of leading the gas away from the top of the fuel bed and combusting it at some more convenient place. This seems to offer some opportunity for re-examination of the technique of ceramic firing with solid fuel. The gas producer, furthermore, offers a couvenient means of making gas for firing in those processes that are best served by a gaseous fuel. Both of the reactions involved in making "air-blown" and ordinary producer gas are important in any theoretical study of the producer-gas process as affecting the ceramic industry. A theoretical study of these reactions is presented, involving both the physical chemistry and thermodynamics thereof.

I. Introduction

In the operation of a ceramic firing process, three factors are important, namely, the intensity (as measured by the temperature), the capacity (as measured by the quantity of heat), and the time. If a uniform product is to be obtained, the ideal situation is to have uniform conditions throughout all parts of the kiln at all times. This is obvious, but how to obtain such uniform conditions is not so obvious. Thermodynamics cannot reveal how such conditions may be accomplished; such a study may indicate the minimum amount of work necessary to accomplish a certain process, but it gives no indication of how much work will actually be required nor the time that the process will take. It may tell whether or not a reaction can proceed and what the maximum yield will be, but it will give no information as to the time required or how to speed it up.

To maintain uniform conditions in the kiln, it is important to liberate heat continuously throughout the kiln as this heat is absorbed by the ceramic reactions or, in the case of radiant firing, to have the ware "in sight" of the source of radiant energy at all times. The liberation of heat throughout the kiln as it is needed can be accomplished by the combustion of gases or by the use of pulverized coal.

II. Producer Gas

The gases leaving the top of any thick fuel bed have practically the same composition as producer gas. In the ordinary practice of firing a fuel bed, the producer gas formed is burned at the top of the fuel bed with secondary air being admitted to accomplish this result. Faur, in 1832, led these gases away from the fuel bed and burned them at some other more convenient place. In 1861, in developing the open hearth, the Siemens brothers applied the producer-gas principle. The producer was a thick fuel bed in a coal-fired furnace using primary air; the gases were led to the hearth at some distance, and the secondary air was admitted at the hearth rather than at the top of the fuel bed.

The term "producer gas" is generally used in the United States to define a gas made by blowing a mixture of steam and air up through a thick fuel bed. It also includes the gases produced when air alone is blown up through a thick fuel bed. The latter gas is also termed "air-blown producer gas" or "Siemens gas." In this discussion, producer gas will be considered to include both of these products.

(1) Air-Blown Gas

When a blast of air is sent through an incandescent bed of carbonaceous material, the carbon is rapidly oxidized to CO_2. This reaction is generally completed within the first 3 in. of the fuel bed, and it is followed by a second reduction reaction.

$$C + O_2 + 3.76N_2 = CO_2 + 3.76N_2; \quad \Delta H = -173{,}921 \text{ B.t.u.}\} 77\,^\circ\text{F}. \quad (1)$$

$$CO_2 + 3.76N_2 + C = 2CO + 3.76N_2; \quad \Delta H = 69{,}521 \text{ B.t.u.}\} 77\,^\circ\text{F}. \quad (2)$$

The thicker the fuel bed, the more complete does reaction (2) tend to proceed, the resulting gas approaching the composition indicated by reaction (3).

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 8, 1940 (General Session on Firing). Received April 9, 1940.

$$\underbrace{2C}_{\text{Fuel}} + \underbrace{O_2 + 3.76N_2}_{\text{Air}} = \underbrace{2CO + 3.76N_2}_{\text{Producer gas}};$$

$$\Delta H = -104{,}400 \text{ B.t.u.} \} 77°\text{F.} \quad (3)$$

An ideal producer gas would consist entirely of carbon monoxide. In technical practice, however, it always contains nitrogen and carbon dioxide. The process is governed from a thermodynamic standpoint by the reaction involving the reduction of CO_2 by carbon, namely,

$$CO_2 + C \rightleftarrows 2CO. \quad (3a)$$

The thermodynamic conditions for the reaction may be obtained from the free-energy equation,

$$\Delta F° = 40{,}910 - 4.9T \ln T + 0.00495T^2 - 0.00000051T^3 - 12.66T. \quad (3b)$$

$$\Delta F° = -RT \ln K_P = -RT \ln P^2_{CO}/P_{CO_2}. \quad (3c)$$

or

$$P^2_{CO}/P_{CO_2} = K_P = e^{-\Delta F°/RT}.$$

It is to be observed from the foregoing equations that the CO will increase as the absolute temperature increases.

From the free-energy equation (3*b*), the theoretical conditions may be calculated for the reduction of carbon dioxide, using air instead of oxygen, that is, by employing reactions (1) and (2). This has been done in Table I. This table shows that a temperature just above 1000°C. (1832°F.) is adequate to yield a gas of maximum practical concentration of CO.

TABLE I

Temp. (°C.)	$\Delta F°$	K_P	Composition of gas (%) CO	CO_2	N_2
700	−1	1.0	22.66	6.08	69.25
727	−1158	+ 1.79	27.67	4.27	68.07
827	−5452	+ 12.09	33.20	0.91	65.88
927	−9725	+ 58.88	34.39	0.20	65.41
1027	−13977	+ 222.89	34.63	0.05	65.32
1127	−18207	+ 692.29	34.69	0.02	65.29
1227	−22416	+ 1833.33	34.71	0.0065	65.28
1727	−43179	+51903.33	34.72	0.00034	65.28

If producer gas is burned according to equation (4), heat is liberated.

$$\underbrace{2CO + 3.76N_2}_{\text{Producer gas}} + \underbrace{O_2 + 3.76N_2}_{\text{Air}} = \underbrace{2CO_2 + 3.76N_2}_{\text{Stack gas}}; \quad (4)$$

$$\Delta H = -243{,}442 \text{ B.t.u. (77°F.).}$$

The composition of this ideal gas and the heating value are as follows:

	(%)	B.t.u./cu. ft.
Carbon monoxide	34.7	0.347 × 311 = 108
Nitrogen	65.3	0
Total	100.0	108 (77°F. dry)

Some of the heat liberated by reaction (1) appears as sensible heat of the producer gas, some as potential heat of the producer gas, and the remainder is lost by radiation from the producer or as heat in the clinkers. An approximate heat balance for the process may be made by assuming that it functions ideally and that the temperature of the entering air is 77°F. and that of the gas leaving the producer is about 1677°F.

Heat input	B.t.u.	(%)
Heat input ($2C + 2O_2 = 2CO_2$)	347,842	100.0
Heat output		
Potential heat in CO	243,442	70.0
Sensible heat in producer gas	67,175	19.3
Radiation and other losses (by difference)	37,225	10.7
Total	347,842	100.0

To calculate the sensible heat of the producer gas, the mean heat capacity of the gas between 77° and 1677°F. must be known. This may be obtained from the equation of Hougen.[1]

$$\bar{C}_p = 6.923 + 0.000373t_f + 0.40 \times 10^{-7}t_f^2.$$

Wherein $\bar{C}_p$ = molal heat capacity in B.t.u./lb. mol./°F.
t_f = temp. °F.

By integrating over the desired range (77° to 1677°F.),

$$\text{Mean } \bar{C}_p = 6.923 + \frac{0.000373}{2}(1677 + 77) + \frac{0.40 \times 10^{-7}}{3}(1677^2 + 1677 \times 77 + 77^2).$$

$$\text{Mean } \bar{C}_p = 7.289.$$

Sensible heat of the dry gas = 5.76 × 7.289 × 1600 = 67,175.

The efficiency may be expressed either as cold efficiency, which in the foregoing case would be 70.0%, or hot efficiency, utilizing the sensible heat of the gases and hence 89.0%. Much of the sensible heat will be lost frequently in practice. This will be the case if the gas must be scrubbed to remove tar or soot or if it is transmitted through long pipe lines.

In considering kiln design and operation from the standpoint of the air-blown producer-gas reactions, the intensity factor, as measured by the temperature of the hot gases, and the capacity factor, which is the amount of heat required to complete the firing reactions, must be considered. (The writer is assuming that uniform conditions of heating are desirable for a uniform product.)

III. Uniform Heat Distribution in Kiln

The temperature at which the producer gas leaves the top of the fuel bed may be controlled to some extent by the draft. The major part of the heat evolution, however, takes place when the secondary combustion occurs, that is, when the producer gas burns with secondary air. If this takes place at the top of the fuel bed, the hottest gases will be present at that point. These gases will become cooler and cooler as they progress toward the stack. It seems obvious that, for uni-

[1] O. A. Hougen and K. M. Watson, Industrial Chemical Calculations; Application of Physico-Chemical Principles and Data to Problems of Industry, p. 114, 2d. ed. John Wiley and Sons, Inc., New York, N. Y., 1936; *Ceram Abs.*, **17** [1] 45 (1938).

form conditions, the combustion of the producer gas must be accomplished throughout the kiln. This can be effected, however, only by control of the locale of admission of secondary air or by imperfect mixing (diffusion firing) because the reaction of $CO + O_2$ to form CO_2 is instantaneous at kiln temperatures.

(1) Steam-Blown Producer Gas

For ceramic firing, the "blow" and "run" of the water-gas process are combined into a single operation, the reactions being essentially those of the cyclic water-gas process. During the blow, air is forced through the fuel bed, thus heating it up to the desired temperature, and the reactions are as follows:

$$C + O_2 = CO_2. \quad (5)$$

$$CO_2 + C = 2CO. \quad (6)$$

The first of these reactions occurs with the liberation of heat; the second, with absorption of heat. Because the heat absorbed in reaction (6) is less than that liberated in reaction (5), the net effect is to store up heat in the fuel bed during the blow.

During the run, water gas is made according to the following reactions:

$$C + H_2O = CO + H_2. \quad (7)$$

$$C + 2H_2O = CO_2 + 2H_2. \quad (8)$$

Both of these reactions occur with absorption of heat. The water-gas process is cyclic, consisting of alternate blowing of the fuel bed with air with consequent raising of the temperature and blowing with steam with resultant lowering of the temperature of the fuel bed.

Because high temperatures favor the formation of CO during both the blow and run, a temperature of operation must be chosen at which maximum economy is attained; this is about 900°C. (1652°F.).

The net effect at equilibrium is governed by the so-called water-gas reaction, which proceeds with the absorption of heat as written.

$$CO + H_2O = CO_2 + H_2. \quad (9)$$

It is rarely convenient in practice, however, to operate under equilibrium conditions, and for this reason reaction rates are important factors. A consideration of these reaction rates leads to the conclusions, verified in practice, that the fuel surface exposed should be as large as possible, the time of contact should be as long as possible, and the temperature of the bed should be as high as possible. Porous materials, such as coke and a deep fuel bed, are thus obviously desirable.

An "apparent equilibrium" has been observed in practice, which depends on the thickness of the fuel bed and is independent of the rate of firing, of the ratio of pounds of steam to pounds of coal, or of the temperature of the exit gas. The equation for the "apparent equilibrium" constant and a table of values are given in equation (10) and Table II.

$$K' = \frac{(Cl_2)\ (H_2)}{(H_2O)\ (CO)}. \quad (10)$$

TABLE II

APPARENT EQUILIBRIUM CONSTANT VS. DEPTH OF FUEL BED

Over-all depth of fuel bed	K'
7	0.66
5	0.48
4.25	0.405
3.5	0.34

The temperature at which the fuel bed may be operated is dependent on the clinkering properties of the mineral matter in the fuels. In a typical gas producer of the continuous type, the blast enters at the bottom through a large supply pipe which is protected from being filled with ash by the blast hood. To protect the blast hood from the high-temperature region, a layer of ash about 18 in. thick is maintained over it. At the top of this region, an abrupt transition occurs to a zone, 8 to 12 in. thick, known as the "braze." The material here is incandescent coke and the temperature may be of the order of 2800° to 3000°F. There is another abrupt transition at the top of the braze to a region of lower temperature containing combustible, which is heated by the gases from below but in which no heat is liberated because all of the oxygen has been consumed in the braze.

In a device such as this, two types of clinker trouble may be experienced during operation and one type in the starting operation from the banked condition. Clinkers large enough to give trouble, however, do not suddenly appear. They grow by accretion as ash is liberated little by little from the burning fuel, but they can grow only if the temperature is high enough to permit the flow of the individual particles as they are released and also to permit these individual particles to weld together.

The first type of clinker trouble in such a producer occurs with ash-yielding slags, which are viscous liquids at the temperature of the braze, i.e., high fusing ashes. This occurs because the viscous slag remains in the braze as it is formed the high viscosity permitting only a slow flow downward. Slag, therefore, accumulates in the braze, and slowly but surely it flows together, eventually yielding a consolidated mass of clinker. If, on the other hand, the slag which is produced is fluid at the temperature of the braze but quickly solidifies at somewhat lower temperatures, an ideal situation exists because the ash is converted to droplets of slag as fast as it is liberated from the fuel. These droplets, being very mobile, trickle rapidly through the braze down into the "ash" zone where the cold blast solidifies them. No accumulation of slag, therefore, occurs in the braze and no clinker can form there.

The second type of clinker trouble occurs in the "ash" zone and is the result of slags, which are mobile enough to flow out of the braze, but, because their viscosity is too low at the temperature of this (the ash) region, they slowly flow together to yield a consolidated clinker.

The third type of clinker trouble begins when the producer is held under bank for many hours and is then put in operation. While under bank, slow combustion

is going on with the liberation of finely divided, unfused ash. When the producer is put in operation, this fine ash accumulates as a layer at the bottom of the braze and is sintered together. Such a sinter cake is troublesome in itself, but, because of the intimate contact of the particles, it is potentially a great hazard, for the slightest flow of its particles will result in the production of a sheet of consolidated clinker over the entire cross section of the producer.

Coming from the gas producer is a fuel of the following approximate composition: CO_2 3.5%, O_2 0.5%, CO 30.0%, CH_4 1.5%, H_2 10.0%, and N_2 54.5%. This gas may be piped to any desired furnace.

IV. Gas Direct from Coal in Furnace

Directly above the fuel bed is a gas of more complex composition (if coal is used) which contains, in addition to carbon monoxide and nitrogen, the hydrocarbons that distill off the coal. The locale of the combustion of this gas will depend on the point of admission of secondary air.

Austin[2] concludes that close control of temperature, of rate of rise of temperature, and of the furnace gases is desirable. Because firing with gas is always simpler than firing with a solid fuel, it would appear logical to operate the solid-fuel furnace as an "air-blown" gas producer and to control the admission of secondary air. This idea is not new; in fact its importance was emphasized by Rice[3] in 1936.

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[2] J. B. Austin, "Physics and Chemistry of Firing Ceramic Ware," *Bull. Amer. Ceram. Soc.*, **14** [5] 157–65 (1935).
[3] W. E. Rice, "Review of Data on Combustion in Kilns," *ibid.*, **15** [10] 325–30 (1936).

SOME METHODS OF FIRING FUELS IN TUNNEL KILNS*

By George D. Brush

Abstract

Tunnel kilns are being widely used in the ceramic industry, and coal, oil, and gas are used successfully as fuels. Various methods of firing these fuels and their relative merits are discussed. Methods used only in commercial tunnel-kiln practice, however, are considered.

I. Introduction

The three methods of transferring heat from the burning fuel to the ware in tunnel kilns are by conduction, by convection, and by radiation. (1) In conduction, heat is transmitted from one particle to another, such as in solid bodies; (2) in convection, heat is transmitted to the ware by the flow of hot gases, for example, the hot gases from burning fuel traveling in and about the ware; and (3) in radiation, the luminous walls and flames from combustion transmit heat to the ware by means of light waves as heat is transmitted from the sun.

These methods of heat transfer are always present in tunnel kilns; the convection method predominates in direct-fired kilns; the radiation method in muffle kilns; and conduction is present in all methods of ceramic firing.

II. Fuels for Tunnel Kilns

The three fuels to be considered are coal, fuel oil, and natural gas. Natural gas and fuel oil are used more frequently because of their ease of handling, their high B.t.u. content, and their availability to ceramic plants. Coal is used chiefly for firing heavy clay products where fuel costs must be low and the dirt from coal handling will have slight effect on the finished product.

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 8, 1940 (General Session on Ceramic Firing). Received April 9, 1940.

(1) Coal

(*A*) *Hand-Stoked Coal:* The use of hand-stoked coal in tunnel kilns is confined chiefly to heavy clayware, although it has been used successfully in firing whiteware. Because of the availability of natural gas and fuel oil, few attempts have been made to use hand-stoked coal for whiteware.

The general arrangement of the firebox using hand-stoked coal is shown in Fig. 1. The grate bars are of the fixed type; they are level and are located so that the top of the fuel bed is flush with or a little below the top of the kiln car; under the grate bars and extending outside the firebox is an ashpan filled with water. Primary air for combustion is introduced under the grate bars and is forced up through the fuel bed, and secondary air is introduced into the firebox just under the crown to insure complete combustion and to supply additional air for an oxidizing atmosphere.

The coal used for combustion should be a good grade with a high fusion ash. Coals from southern Kentucky and West Virginia have given the best results. Each firebox is fired every 15 to 30 minutes. The coal is placed first on a coking table just inside the firebox door. When the next firing charge is ready to go into the firebox, the previous charge on the coking table is pushed off onto the grates, and the new charge is placed on the coking table, by which process uniform firing conditions are maintained.

The fireboxes usually are carried under draft. In some cases, however, those located toward the discharge

end of the kiln are carried under a neutral or slightly positive pressure to obtain more uniformity in the ware tunnel.

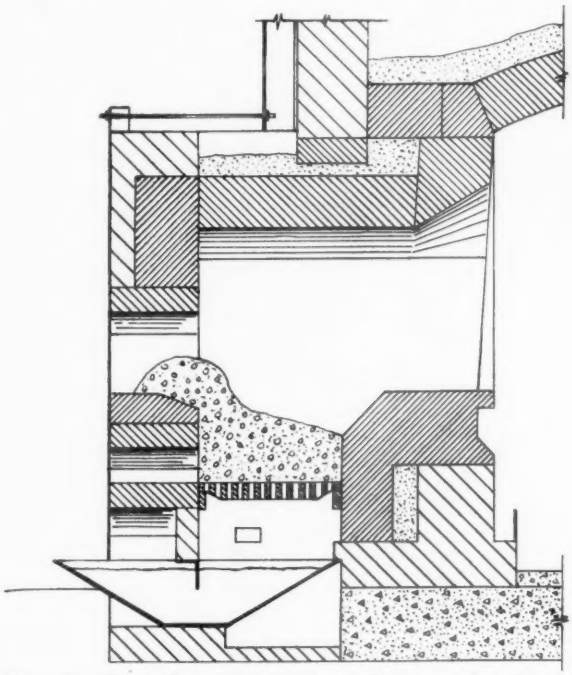

FIG. 1.—General arrangement of firebox using hand-stoked coal.

(*B*) *Mechanical Stoker-Fired Coal:* Many types of stokers have been tried on tunnel kilns, but the most successful is the underfeed type (Fig. 2). The bowl and tuyères are mounted in the firebox, and coal is fed up through the bowl by means of a screw or plunger. When regular stoker coal is used, the screw-type of feed may be used, but the plunger-type of feed is the best when run-of-mine coal is used.

All of the stokers are operated from one line shaft on each side of the kiln, and the amount of coal feed is regulated by the length of stroke of the plunger.

The screw-type stoker is operated generally by individual motors, and the coal-feed type is regulated either by turning the stoker on and off or by means of adjustable gears or cams.

The primary air on underfeed stokers is introduced through the tuyères surrounding the bowl. This air may be supplied by individual fan units or from a central air-supply fan. Secondary air is introduced above the fuel bed by the same method used for hand-stoked coal.

One of the early troubles encountered with coal firing in tunnel kilns was the fluxing of the ash and clinker with the firebrick lining of the firebox. Air was circulated with considerable success in back of a $4^1/_2$-in. firebrick lining at the level of the fuel bed. The best results were obtained when silicon carbide brick were used to line the fireboxes at all places in contact with the ash and clinker, which permitted a long-time operation without the necessity of closing down to repair the firebox linings.

(*C*) *Powdered Coal:* Only one tunnel kiln in the United States is fired with powdered coal. The coal is pulverized and fed to each firebox in a manner similar to that used for producer gas. When powdered coal is used, it is necessary to start the tunnel kiln with natural gas or with fuel oil. After the fireboxes have reached their working temperatures, the powdered coal is used to continue the combustion and heating. The fly ash that is left over the ware when it comes from the kiln is one of the chief drawbacks to the use of powdered coal. It is necessary to pass the cars in front of a high-velocity fan and to blow off the fly ash, which creates a difficult dust hazard.

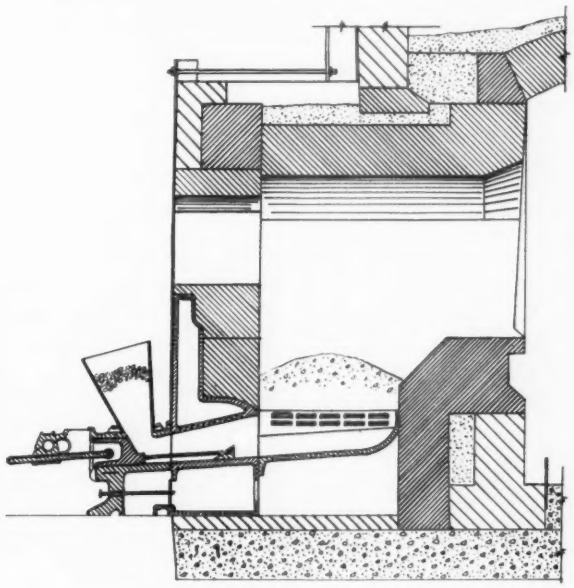

FIG. 2.—Underfeed-type of stoker.

(2) Oil

For oil firing, light or heavy fuel oils are used. In firing light oils, little or no heating is necessary to obtain the proper flow of the oil, except in extreme cold temperatures such as are encountered in the northern part of the United States. With the heavier fuel oils, such as "bunker C," it is always necessary to heat the oil to obtain the proper flow in the oil lines and atomization through the burners.

The customary method is to pump the oil from the storage tank through the filter screens, the air and water separator, the heating coils, or the steam heater, then past each burner, and back to the storage tank. A relief valve is placed in the line beyond the last burner to insure any definite oil pressure on the line past the burners. Branch oil lines are run to each burner or group of burners to regulate the flow of oil. A pressure of 15 to 30 lb. of oil is generally used. The burner connections are shown in Fig. 3.

The air for the burners is supplied by a blower or fan. Air pressure to the burners for oil firing should be at least 16 oz., and pressures up to 24 and 30 oz. are not objectionable. When relatively small amounts of air

are required, the single-stage blower or fan is used, and when larger amounts are needed, the multistage blower is the best. An added advantage of the multistage blower is the more quiet operation.

The air to the burners may be preheated or used at ordinary room temperature. Preheated air gives a relatively quick and soft flame during combustion, and air at room temperature gives a sharper and a more driving combustion.

The oil burner is simply a device to atomize the oil into a fine spray, to mix this spray with air, and to force the mixture into the combustion space. The velocity of the mixture should always be sufficient to keep the combustion within the firebox. The burners should be flexible enough to permit high or low oil consumption as the occasion demands.

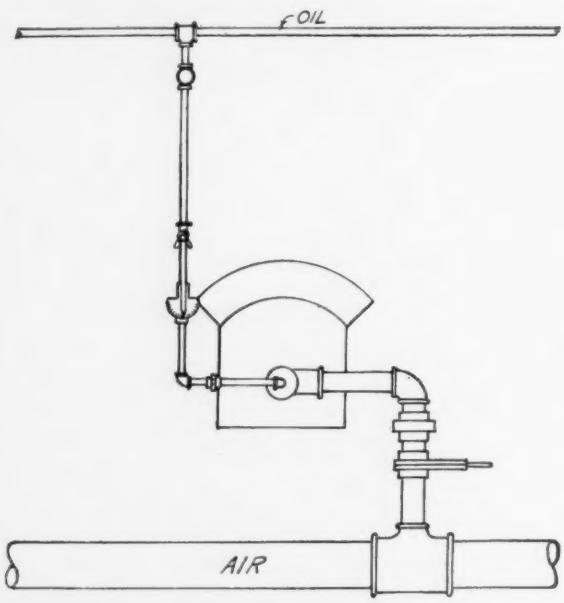

FIG. 3.—Burner connections for oil firing.

(3) Natural Gas

The burner system for natural gas is more simple than that for oil firing. Natural gas is piped direct to the kiln from the gas regulator house, and the gas line is run along the firing zone with branches to each burner or to a group of burners. The gas line in some cases is split at the end of the firing zone and run down each side of the tunnel kiln.

The same air-supply system is used for natural gas as for oil. Air pressures for natural gas may be as low as 8 oz. and still give good results.

There are two general burner systems used in connection with natural gas. The first method is to bring both the gas and air under pressure to the burner. Hand controls on the air and gas permit the operator to get the right mixture for the combustion desired. More gas and less air will give a long flame, whereas more air and less gas will give a short snappy flame (see Fig. 4 for burner connections).

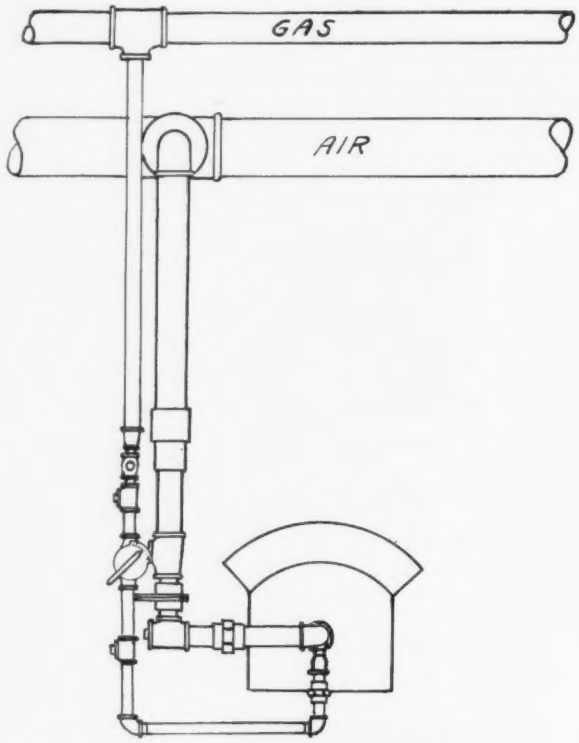

FIG. 4.—Burner connections for natural gas firing.

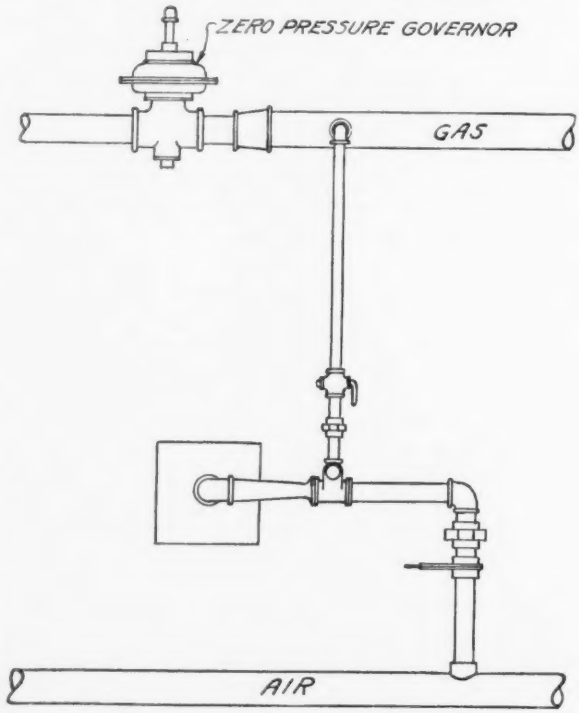

FIG. 5.—Venturi burner showing burner connections.

The second method of burning gas is to bring the gas to the burner at zero pressure and the air at full pressure. As the air passes through the venturi burner,

the right amount of gas is pulled into the air stream through an adjustable orifice (see Fig. 5). The ratio of air and gas is constant for any given opening on the gas orifice. The amount of combustion taking place is then controlled by the amount of air passing through the burner. The temperature throughout the fire zone may be easily raised or lowered by adjusting the main blast gate on the air supply.

III. Direct-Fired Tunnel Kilns

In direct-fired tunnel kilns, the burners are installed at right angles to the flow of ware. These burners are placed on either side of the kiln at a point approximately midway from the ends. The burners are spaced from 3 to 11 ft. apart. Two burners are used in some fireboxes, one above the other. The burners are regulated so that the high temperature in the tunnel is toward the end of the burner system. The leading burners are used to build up the temperature to the high-temperature section and the tail-end burners carry through a soaking action after the peak temperature is passed. In cases where a long burner section on the kiln is used, the middle group of burners maintains a long soaking action at the peak temperature.

Preliminary or auxiliary burners are used in many tunnel kilns in the charging end to help maintain uniform temperatures from the top to the bottom of the ware setting. With natural gas, the burners fire directly into the kiln through openings just above the car top. Because of the cutting flame of the oil burners, preliminary heating with oil must be done through combustion chambers on either side of the kiln, and only the heated gases are allowed to flow into the tunnel just above the car top.

IV. Muffle Tunnel Kilns

In muffle tunnel kilns, the burners are placed at an angle toward the charging end or parallel to the ware movement and directed toward the charging end. A long, luminous flame is carried as much as possible on the burners. This flame is caused to wipe along the muffles to get the greatest possible amount of heat transfer. Because of the tendency of heat to rise, the burners are usually located along the bottom section of the muffle. Neutral or slightly reducing conditions are maintained through the burners and combustion is completed by the introduction of secondary air, which permits slow combustion to take place and which is effective in muffle kilns.

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FACTORS AFFECTING THE LIFE OF KILN FURNITURE IN THE WHITEWARE INDUSTRY*

BY GRANT S. DIAMOND

ABSTRACT

Various refractory bodies, including silicon carbide, mullite, fused alumina, and fire clay, as commonly used for tunnel-kiln furniture in the whiteware industry, were studied. The relationship of the physical properties to thermal flexibility as well as the use of the Winklemann and Schott formula for determining thermal flexibility is considered. The practical use of this value and other properties in computing maximum slab length and thickness is shown. Common causes for heat variations in kilns and methods for correcting them are discussed with relation to slab failures. Construction of open-setting tunnel-kiln cars, saggers and a new method for open firing of glost ware are reviewed and illustrated.

I. Introduction

Kiln furniture, owing to its initial and maintenance cost, is an appreciable item of expense per ton of ware. The fuel cost of heating large tonnages of refractories is also an important manufacturing expense. It is essential, therefore, that the ratio of kiln-furniture weight to the ware weight be as low as is compatible with required service strength. Repairs or replacements of tunnel-kiln refractories affect the production schedule, especially when circular kilns are used.

Heindl and Pendergast[1] have shown the relation of tensile strength and elasticity to sagger performance. One design suggestion for a clay sagger will be included in this paper, but the chief emphasis will be placed on the comparative suitability of clay, calcined kyanite (sillimanite or mullite), silicon carbide, and fused alumina for use as slabs in the open setting of ceramic ware.

Tests have been run on typical samples of four types of slab compositions, and their physical properties are tabulated in Table I. Two samples each of silicon

* Presented at the Forty-First Annual Meeting, The American Ceramic Society, Chicago, Ill., April 19, 1939 (White Wares Division). Received February 24, 1940.

[1] R. A. Heindl and W. L. Pendergast, "III, Progress Report on Investigation of Sagger Clays: Their Elasticity and Transverse Strength at Several Temperatures," *Jour. Amer. Ceram. Soc.*, **10** [7] 524–34 (1927).

TABLE I

PHYSICAL PROPERTIES OF SAMPLES

Sample No*.	K	T	c	d	MR (°F.) 2000	MR (°F.) 2462	t (°F.) 80	t (°F.) 1500	t (°F.) 2000	t (°F.) 2400	E (°F.) 80	E (°F.) 1500	E (°F.) 2000
1	110	5.2×10^{-6}	0.18	2.42	1782	1340	920	1470	1020	985	6.80	10.30	6.30
2	100	5.2 " "	0.18	2.40	1596	1200	755	1175	755	605	6.25	7.20	7.50
3	11	4.7 " "	0.23	2.24	353	130	245	354	301	115	1.57	1.70	
4	11	4.7 " "	0.23	2.17	300	110	230	238	285	181	1.16	1.25	
5	30	5.0 " "	0.28	2.68		525	760	615	318	175	5.35	5.35	
6	9	5.6 " "	0.27	2.00	204	57	400	215	152		6.09	6.55	

K = thermal conductivity (B.t.u./sq. ft./hr./°F./1 in. thick).
T = coefficient of thermal expansion (in./in./°F.).
c = sp. heat (gm. cal./gm./°C.).
d = density (gm./cc.).
MR = modulus of rupture (lb./sq. in.).
t = tensile strength (lb./sq. in.).
E = modulus of elasticity (millions lb./sq. in.).

*Sample No.
1 = high-tensile SiC.
2 = low- " "
3 = high- " mullite.
4 = low- " "
5 = fused alumina.
6 = grade "A" fire clay.

carbide and mullite are included because they are popular compositions for such refractories. Modulus of elasticity, modulus of rupture, density, specific heat, and tensile-strength values were determined. These tests were made on several samples of each of the test formulas at each temperature shown in the table. An exhaustive study was not undertaken, but a sufficient number of elasticity and tensile tests was made to secure reliable results. The total study required about 175 tests divided among the six formulas. The thermal-conductivity values were taken from work by Endell,[2] Norton,[3] and Hartmann and Westmont.[4]

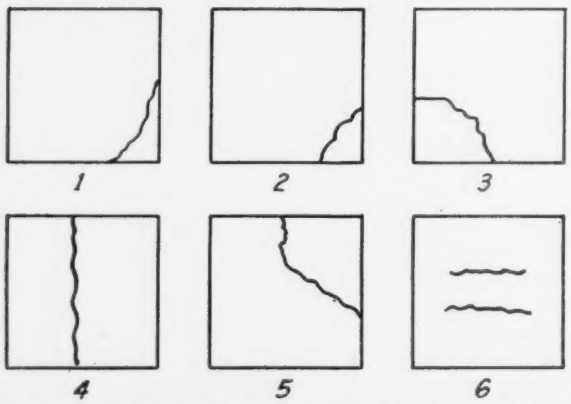

FIG. 1.—Type of slab failure caused by thermal shock; *curves:* (1) shearing crack from rapid heating; (2) crack caused by weakness or by lack of support; (3), (4), and (5) tensile cracks from rapid cooling; (with (4) occurring the most frequently); (6) crack caused by poor circulation in kiln on heating.

II. Thermal-Shock Study

Figure 1 shows the types of slab failure occurring in tunnel kilns; No. 1 is an example of shearing stress caused by unusually rapid heating (this type of failure is rare); No. 2 is caused by mechanical weakness (particularly tensile strength) of the slab or by poor support or overloading at the corners; and Nos. 3, 4, and 5 are tensile failures (No. 4 is the most frequent and is caused by rapid cooling of the slabs).

(1) Formulas to Determine Resistance to Thermal Shock

Winkelmann and Schott formula[5]

$$R = \frac{t\sqrt{K}}{TE\sqrt{dc}}.$$

Heindl and Pendergast formula[1]

$$R = \frac{M}{ET}.$$

Wherein R = resistance to spalling.
t = tensile strength (lb./sq. in.).
M = modulus of rupture (lb./sq. in.).
K = coefficient of thermal conductivity (B.t.u./-hr./°F./sq. ft./in. thick).
T = coefficient of thermal expansion (in./in./-°F.).
E = modulus of elasticity (lb./sq. in.).
d = density (gm./cc.).
c = specific heat.

The Winkelmann and Schott[5] formula is of questionable value for calculating the thermal-shock resistance of 9-in. straight brick when it is applied to standard spalling tests, but it is suitable for application to refractory pieces of considerable length and breadth and of small thickness where tensile stresses are developed higher than shearing stresses. The formula used by Heindl and Pendergast[1] on all-clay samples is an abbreviation of the Winkelmann and Schott formula, and it is obtained by omitting the diffusivity, $\sqrt{K/dc}$, and the coefficient of expansion, T. The t of Winkelmann and Schott is replaced by M, which is the modulus of rupture determined on a 1-in. square sample with a 10-in. span. The value of M under these conditions is practically equal to the tensile strength.

[2] K. Endell, "Zur Berechnung der Temperaturwechselbeständigkeit feuerfester Steine aus ihren physikalischen Konstanten," *Glastech. Ber.*, **11** [5] 178–82 (1933); abstracted in *Chim. & Ind.*, **30** [5] 1113 (1933); *Ceram. Abs.*, **13** [4] 90 (1934).

[3] F. H. Norton, "Heat Flow in Refractories," *Fuels and Furnaces*, **10** [9] 575 (1932).

[4] M. L. Hartmann and O. B. Westmont, "Thermal Conductivity of Carborundum Refractories," *Jour. Amer. Ceram. Soc.*, **8** [5] 259–95 (1925).

[5] A. Winkelmann and O. Schott, "Über thermische Widerstandscoefficienten verschiedener Gläser in ihrer Abhängigkeit von der chemischen Zusammensetzung," *Ann. Phys. Chem.*, **51**, 730–46 (1894).

The value of E in Young's modulus of elasticity is

$$E = \frac{PL^3}{4\Delta bd^3}.$$

Wherein E = Young's modulus of elasticity.
P = load (lb.).
L = span (in.).
Δ = deflection (in.).
b = breadth (in.).
d = thickness (in.).

The value of E has been determined by flexure tests, using a 10-in. span with direct-weight applications of 10, 20, or 30 lb. or more at room temperature and at 1000°, 1500°, 2000°, and 2400°F. (Fig. 2). Only samples Nos. 1 and 2 gave satisfactory figures above 1500°F. The others apparently exceeded the elastic limit when tested beyond this temperature.

Figure 3 shows the furnace used in these tests, which is similar to that used by Heindl and Pendergast and is capable of obtaining a temperature of 2500°F.

Figure 4 shows the high-temperature, tensile-strength test furnace used to obtain values of t. The silicon-carbide jaws were necessary because of the high temperature used.

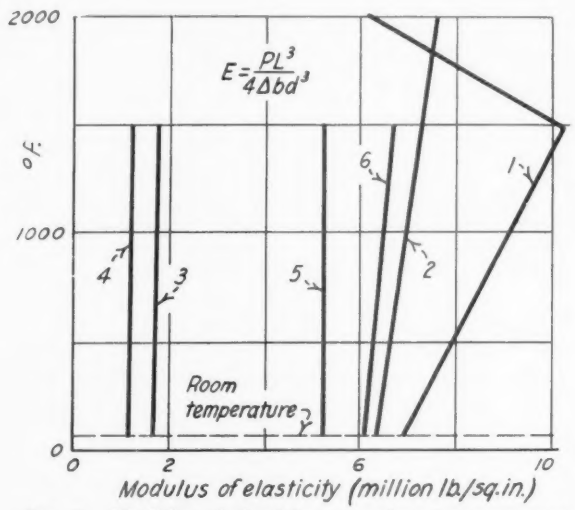

FIG. 2.—Modulus of elasticity at various temperatures; *curves:* (1) high-tensile silicon-carbide mix; (2) low-tensile silicon carbide; (3) high-tensile mullite; (4) low-tensile mullite; (5) fused alumina; (6) grade "A" fire clay.

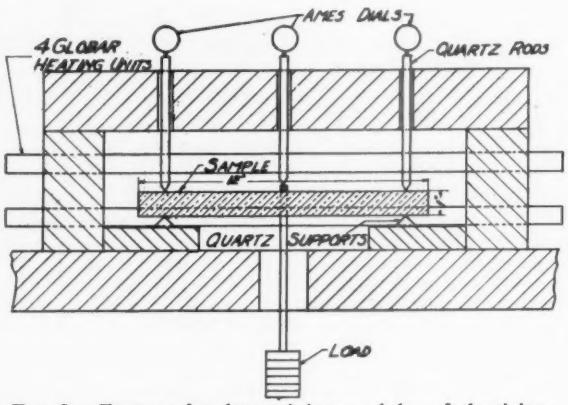

FIG. 3.—Furnace for determining modulus of elasticity.

The samples are similar in shape to the usual concrete tensile-strength biscuits, except that the 1-in. square cross section was made 10 in. long and the samples were heated so that the middle third of the length was up to the required temperature although the ends were considerably cooler. Temperatures were determined by an L.&N. optical pyrometer, sighted directly onto the center of the sample. All fractures occurred within the central area.

Figure 5 shows the tensile-strength values at various temperatures.

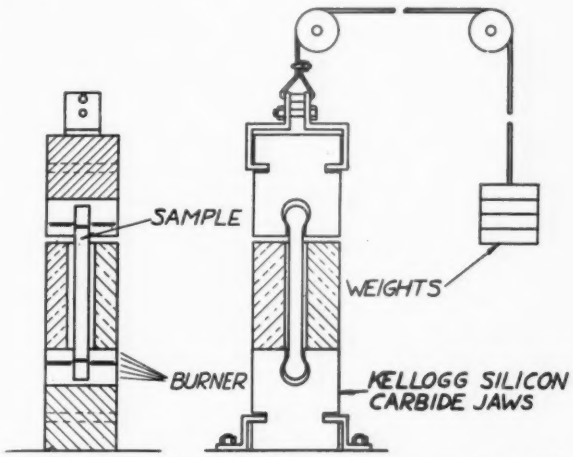

FIG. 4.—Furnace for determining tensile strength at high temperatures.

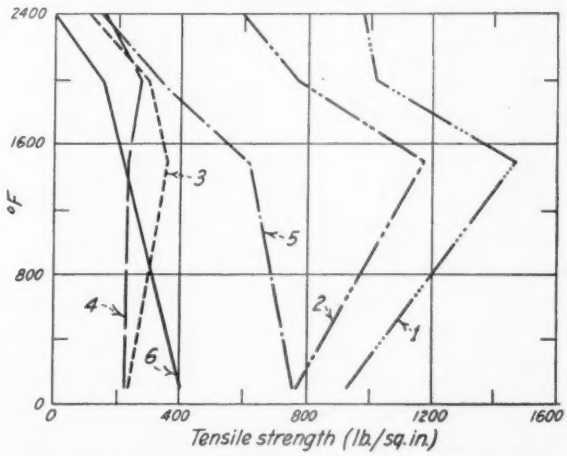

FIG. 5.—Tensile strength at various temperatures; *curves:* (1) high-tensile silicon carbide; (2) low-tensile silicon carbide; (3) high-tensile mullite; (4) low-tensile mullite; (5) fused alumina; (6) grade "A" fire clay.

Table II and Fig. 6 show the values of R for the six samples at different temperatures. This is called "thermal flexibility," as it is really the flexibility formula, t/E, corrected for temperature changes by introducing thermal conductivity, heat capacity, and coefficient of thermal expansion. Sample No. 2, the low-tensile silicon carbide, has the highest thermal flexibility of the materials tested because of its lower elasticity modulus as compared to sample No. 1.

Each element, such as the coefficient of expansion, the diffusivity, the modulus of elasticity, and tensile strength, in the "thermal-flexibility" formula has an important effect on the value of R. When any of these values are changed, a different R value results. Most of these values, however, are not easy to change.

TABLE II

Sample No.	R values (°F.) 80	1500
1	413	435
2	354	478
3	153	204
4	198	189
5	179	145
6	48	24

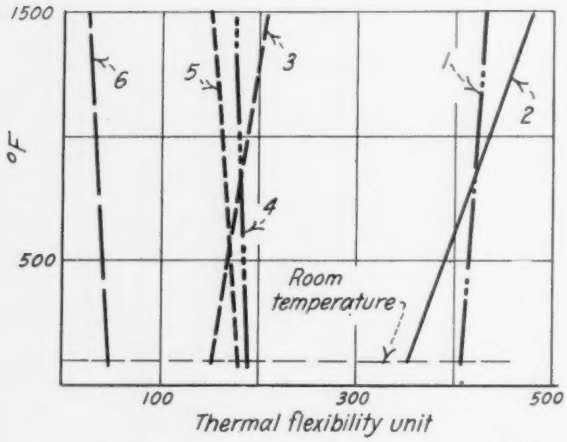

FIG. 6.—Values for R thermal flexibility, $R = \frac{t\sqrt{K}}{TE\sqrt{dc}}$. *Curves:* (1) high-tensile silicon-carbide mix; (2) low-tensile silicon carbide; (3) high-tensile mullite; (4) low-tensile mullite; (5) fused alumina; (6) grade "A" fire clay.

The elements most easily varied are the tensile strength and modulus of elasticity. The advantage of varying these two properties is demonstrated by comparing sample No. 1 with No. 2 and No. 3 with No. 4. In sample No. 2, the elasticity was improved by using a coarser grog than in No. 1, with a resultant gain in the value of R. In No. 3, the tensile strength was improved over No. 4, with the elasticity remaining about the same but with a resultant increase in the value of R. These improvements indicate the value of further research on thermal flexibility.

The curve showing sample No. 5 indicates why fused alumina, which is an excellent refractory for many purposes, has never proved successful for tunnel-kiln slabs.

A few samples of equal size were tested on a rapid-cooling cycle to determine how closely the life corresponds with the calculated values of R. Three samples of each formula (18 pieces) were tested. More exhaustive tests will be required before positive claim can be made that the R formula is proved.

Only tensile stresses were developed in the thermal-shock tests. Shearing stresses were minimized by a slow temperature rise when heating the samples, but a rapid chilling was used to develop the maximum tensile stresses on cooling.* The results check the R formula closely, as indicated by the curve drawn through points obtained by plotting the actual failure values against the respective calculated R values (Fig. 7). The curve is parabolic and similar to that obtained by Norton[6] on thermal-shock shearing strains.

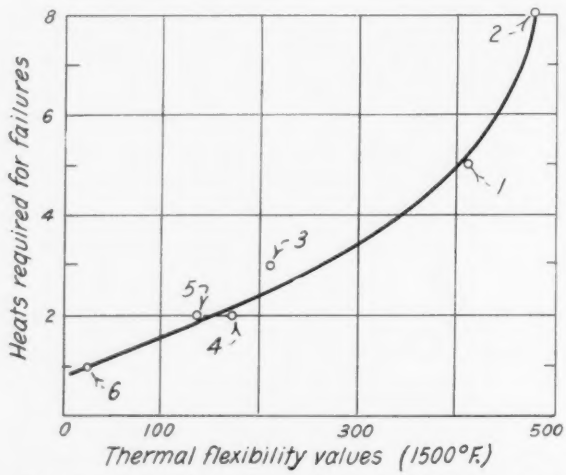

FIG. 7.—Comparison of actual tensile failures and calculated thermal-flexibility values; *curves:* (1) high-tensile silicon carbide; (2) low-tensile silicon carbide; (3) high-tensile mullite; (4) low-tensile mullite; (5) fused alumina; (6) grade "A" fire clay

The fire-clay sample is the least resistant to cooling shock, and the two silicon carbides are the most resistant. From observations and reports from numerous potteries where silicon carbide, mullite, fused alumina, and fire clay have been tested, the relative values of R for these refractories have been substantiated in actual service.

III. Influence of Slab Length

Referring to the values of R shown on Fig. 6, it may be deduced that they represent the relative maximum lengths of the different refractories when they are used under identical conditions. The tensile stresses developed in chilling slabs are obviously proportional to the length of the slabs, inasmuch as the stress is dependent on the coefficient of thermal expansion or contraction and on the change in temperature. Because this is true, it may safely be assumed that the mix with the

* Samples, 9 by $4\frac{1}{2}$ by $1\frac{1}{4}$ in., were slowly moved into openings left in the front wall of a furnace operated at 2462°F. They were brought up to temperature in an hour and were subjected to an air blast against the hot end for 10 minutes. The number of cycles required to cause cracking was taken as the resistance to thermal shock; the cracks were types No. 3 or No. 4, shown on Fig. 1.

[6] F. H. Norton, Refractories, 1st ed., Fig. 12, p. 355. McGraw-Hill Book Co., New York, N. Y., 1931; *Ceram. Abs.*, **11** [1] 40 (1932).

best R value may be used successfully in large slabs and that the mix with the poorest R value will be successful only on short slabs. The maximum successful lengths, moreover, should be directly proportional to the values of R (Fig. 6).

In Fig. 8, bar graphs are given which denote recommendations of maximum lengths for these refractories for average tunnel-kiln conditions. The 40-inch length for silicon carbide sample No. 2 is arbitrary and is selected because it is the largest slab in successful service in a tunnel kiln. The lengths for the other refractories are drawn in direct proportion.

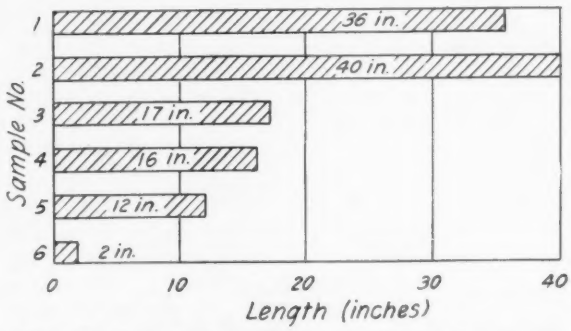

FIG. 8.—Suggested maximum slab length for average tunnel-kiln conditions; *sample:* (1) high-tensile silicon carbide; (2) low-tensile silicon carbide; (3) high-tensile mullite; (4) low-tensile mullite; (5) fused alumina; (6) grade "A" fire clay.

IV. Slab Thickness

From the modulus of rupture formula,

$$MR = \frac{3Pl}{2bd^2},$$

the following formula has been determined for the thickness of slabs for carrying loads at high temperatures:

$$d = 4\sqrt{\frac{3Pl}{2b(MR)}}.$$

In which 4 = factor of safety.

The value of MR is variable for different refractories and it also varies with temperature. Table I contains the most important of these values.

For a slab measuring 24 by 36 inches, supported only at the four corners, and carrying a load of 100 lb. at 2462°F., sample No. 1 (SiC) requires 1.64 in.; No. 2 (SiC), 1.76 in.; and No. 3 (mullite), 5.24 in. thickness.

At 2000°F., sample No. 1 (SiC) requires 1.42 in.; No. 3 (mullite), 3.16 in.; and No. 6 (fire clay), 4.20 in. thickness.

By means of the thickness formula, the minimum thickness of slabs may be determined for particular loads and spans. The factor of safety, 4, is suitable for simple rigid construction. With floating construction, this factor may be reduced considerably.

V. Saggers

Although slabs have been referred to exclusively, the comparative R values shown will indicate thermal flexibility of saggers made out of these materials. The maximum-length graphs probably would not apply on these shapes. The cycle of many porcelain kilns is very fast, and the maximum successful dimensions are usually 20 in. or less for silicon carbide saggers.

VI. Heating Variations in Kilns

Figure 9 gives the explanation for several kiln-furniture failures. This heat curve is typical of the gradient found in many high-temperature, fast-cycle kilns. The curve shows two points where temperature shock is very severe. For example, the pyrometer at the entry end shows a temperature rise of 275°F. in 40 minutes or the rate of 410°F. per hour. This may cause shearing cracks at the corners of the slabs; such shearing failures occur in this kiln but fortunately not to a serious extent. This kiln, however, causes expensive slab breakage owing to the tensile stresses in the cooling area; a sharp drop in temperature from 2300° to 1500°F. just beyond the hot zone occurs in a period of 3.7 hr. or at a cooling rate of 243°F. drop per hr. The explanation for this drop is that cold air is blown into the furnace walls at this point to chill the cars. Some levels of the slabs probably receive actual impinging air currents which are much colder than the 1500°F. shown by the pyrometer. The dotted line suggests a more desirable gradient.

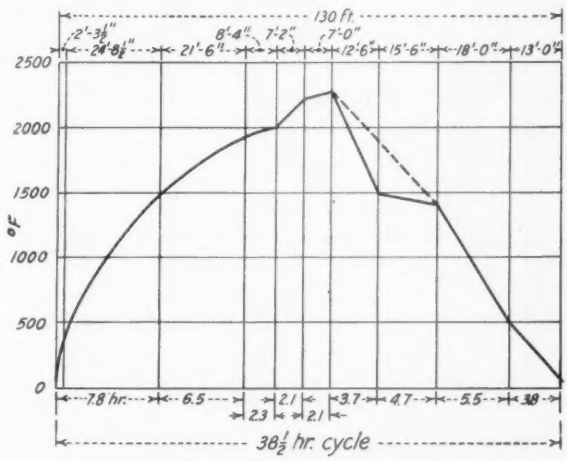

FIG. 9.—Heat curve for porcelain plant.

Chilling the ware and the furniture by air, or "resistance" as it is called, is rather commonplace in tunnel kilns. One purpose of the chilling is to shorten the cooling time of the cars and thus obtain the shortest cycle possible for a given length of kiln. This, of course, effects an economy of investment and space, but the life of the kiln furniture suffers. In some kilns, the cooling air is introduced at the exit end and directed toward the hot zone, which sounds like a proper use of the counterflow principle in heat exchange. The thermal shock is reduced to the minimum, and there is also efficient heat exchange. If the counterflow method introduces too much pressure, which affects the high-temperature zone adversely, the volume of air may be reduced and the heat exchange may take place by means of metal chambers inserted on the inside walls of the kiln through

which cold air is circulated. One such combination of counterflow and air-cooled wall installation is in successful service in a porcelain plant. The cost of improving such chilling conditions was quickly repaid by the longer life of slabs and saggers.

It is not uncommon to observe tunnel-kiln cars that are red hot at the top and black at the bottom on the upward gradient of a kiln. The opposite is true on the cooling gradient. Such differentials in temperatures do not permit even expansion and contraction of the kiln furniture. Certain decks receive too great a thermal shock, whereas the heat lag in other decks prevents equalization of stresses. With proper circulation, cycles may be fast without damage to the kiln furniture; with improper circulation, even slow cycles may develop local hot spots or cold spots with resultant tensile failures.

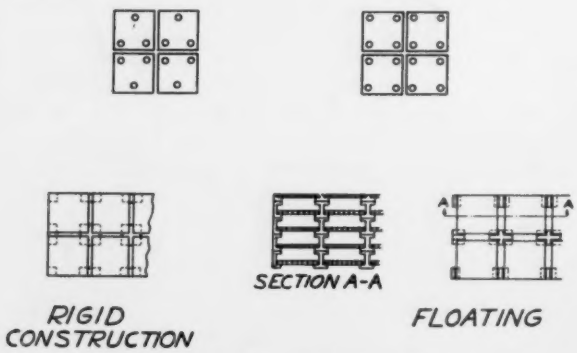

FIG. 10.—Plan views of several tunnel-kiln car post and slab arrangements.

VII. Construction Designs

Figure 10 shows plan views of four post and slab arrangements for tunnel-kiln cars. The rigid construction (lower left) is still the most popular arrangement. Owing to the use of individual posts to support two or four slabs, the number of posts is kept at a minimum so that excellent setting capacity is obtained. This type of setting, however, is not ideal so far as mechanical stresses are concerned. The slabs and posts are held together rigidly, and any variation in temperature from top to bottom or from side to side will tend to strain the slabs, owing to the unequal expansion or contraction. With this type of setting, any heaving of the car top will cause fracture of the slabs at the corners. The plan at the upper right has the advantage of less rigidity, but it still retains the superimposed corner loads.

This arrangement has one good quality in that the horizontal spacing between slabs may be varied to suit the maximum overhang of bisque flatware. Such spacing is an advantage in promoting circulation, and in addition it permits the use of the minimum size of slab per dozen of ware. As slabs are priced by size, this means lower slab cost per car.

The plan at the upper left (Fig. 10) is popular in porcelain plants where the slabs are removed after each cycle and then rebuilt with the desired spacing between decks. The three-point suspension eliminates the possibility of poor support at a corner which the four-post setting cannot guarantee. This is practical for light loads.

The other illustration is the floating construction which eliminates mechanical stresses and also permits the removal of any slab without affecting the remainder of the structure. Minimum-sized slabs (permitting overhang), minimum thickness, good circulation space, and general convenience are apparent in this type of setting.

Figure 11 (*A*) shows a rigid construction with silicon carbide slabs, 32 by 17 by 1 inch in size, which allows high-density setting. The car top or table top as it is called in circular kilns is more or less uneven owing to sand spillage, whereby the sand gets down in the joints of the car-top brick in the car and causes heaving, which is detrimental to a rigid construction. The car tops should be made in large sections of cast refractory, and if any joints are necessary they should be covered to prevent sand trouble.

Figure 11 (*B*) shows a similar construction, in which an attempt has been made to use larger tile and to cover the joints with rails. This is an improvement over Fig. 11 (*A*). An additional improvement, not visible in the picture, is the use of smaller sections of slabs.

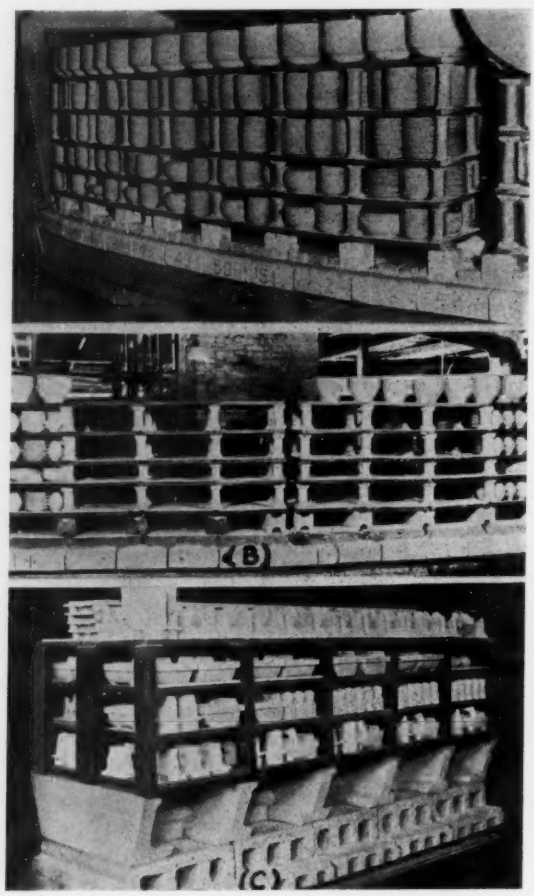

FIG. 11.—Tunnel-kiln settings.

Many circular kiln settings are built up 5 decks high and 6 or 7 tiers wide per section of setting. Fewer tensile failures will result with 4 tiers wide or a maximum of 6 feet along the outer periphery of the table top. The tensile strains produced in heating and cooling rigid constructions are proportional to the length of the structure.

Figures 11 (*C*) and 12 (*A*) show floating construction in porcelain kilns. The car tops are a combination of fire-clay rails with silicon carbide shelf posts. The posts are sturdy even though the clay rails are rather narrow. Wider fire-clay footings, however, are recommended.

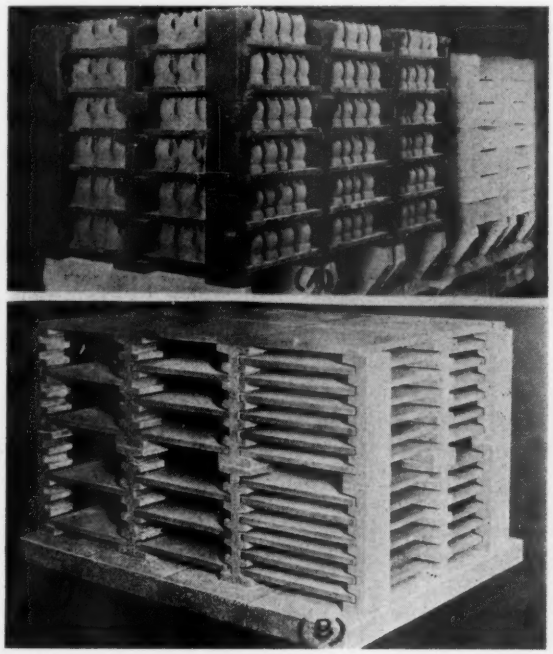

FIG. 12.—Tunnel-kiln settings.

Figure 12 (*B*) shows a construction which is used by one of the ceramic colleges for firing ware. The shelf posts are made with enough ledges so that deck spacings may be varied from $1^1/_4$ in. to several feet. The slabs are removable in such floating constructions and support only their own weight.

Figure 13 shows the floating type of sagger which relieves the stresses and the strains between the side walls of the sagger and the bottoms. The saggers pictured are used in porcelain plants and are made with silicon carbide ledge-type rings and silicon carbide plates to serve as bottoms for the saggers. This type of sagger does not need to be limited to super-refractories; clay saggers could be made in the same floating type. At the temperatures where bottom sagging occurs when clay is used, the loose bottom plate may be made of silicon carbide. There are several porcelain plants using this type of sagger with successful results. Most of the saggers used have been all silicon carbide, but one plant is getting satisfactory results with mullite.

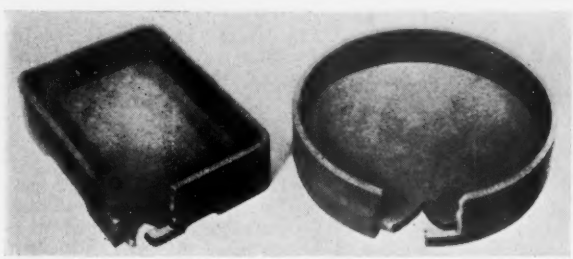

FIG. 13.—Floating sagger.

VIII. Open Setting of Glost Flatware

Figure 14 shows the "horseshoe"-type setters, which have been used successfully in some California potteries for glost firing. This open setting of glost ware represents a reduction in firing costs.

Open setting of bisque ware provides such good density that one bisque tunnel kiln can provide enough ware to operate two or more glost kilns. It is therefore readily realized that the weight of kiln furniture in

FIG. 14.—"Horseshoe" setters.

sagger setting of glost ware is excessive. Tremendous fuel saving is possible with dense open setting of glost ware.

Horseshoe setters are also adapted to mechanical setting and loading, by which it is claimed that setting labor can be reduced by 75%.

IX. Summary

(1) The thermal flexibility of kiln furniture has a direct bearing on size and performance of furniture. (2) Modulus of rupture value controls the thickness of the furniture. (3) The type of construction used affects the life, ware density, and efficiency of settings. The importance of the heat curve and circulation in tunnel kilns in relation to the life of furniture has been pointed out, and the possibilities of open setting of glost flatware has been indicated.

Electro Refractories and Alloys Corporation
Buffalo, New York

CERAMIC HISTORY

EUGENE C. SULLIVAN

Eugene Cornelius Sullivan was born at Elgin, Illinois, January 23, 1872, the son of Thomas E. and Mary A. (Richards) Sullivan. Thomas E. Sullivan was foreman in the composing-room of the *Chicago Tribune* staff in Chicago, but, because of the Chicago fire, he was residing temporarily in Elgin at the time of the birth of his son. Eugene Sullivan received his primary education in the city schools of Chicago and was graduated from the North Division High School in 1890. He then attended the University of Michigan, where he received the B.S. degree in Chemistry in 1894, and he has always been a loyal Michigan alumnus. A few years after graduation, he was elected to Phi Beta Kappa. From 1899 to 1903, he was instructor in analytical chemistry at the University of Michigan. In 1933, Michigan gave him an honorary Doctor of Science degree. Dr. Sullivan received his graduate training in Germany, going to Göttingen in 1896 and finishing at the University of Leipzig in 1899, when he was given the degree of Doctor of Philosophy.

He began his professional career in 1893 as an assistant in the Department of Mines and Metallurgy at the World's Columbian Exposition in Chicago. After his graduation from Michigan, he was first a chemist at the Aetna Powder Company, Aetna, Indiana, then a chemist in the Price Baking Powder Company, Chicago, Illinois (1894–1896). This initial industrial experience served to stimulate his ambition for further study and research, and his scientific education and training were continued in Germany and on the staff at Michigan. He formed many friendships among his educational associates and has retained most of them throughout his later life.

Leaving the University of Michigan, Dr. Sullivan was a chemist in the Geological Survey from 1903 to 1908. During this period with the Geological Survey, he came into intimate contact with two men who undoubtedly had a great influence on his career. One of these was A. L. Day, soon to be made director of the newly formed Geophysical Laboratory of the Carnegie Institution, who became one of his closest friends. Another was W. F. Hillebrand, who later became chief chemist of the National Bureau of Standards, a lovable man whose high scientific ideals profoundly affected the progress of analytical chemistry.

In 1908, Dr. Sullivan became associated with the Corning Glass Works as chief chemist, and later, after organizing a laboratory and staff, he became the director of research. In 1921, he was made vice-president in charge of manufacturing, and in 1928 he became president of the Company. He served in that capacity for one and one-half years. Although the Company was particularly successful during the Sullivan period of administration, his personal tastes were decidedly for the problems of manufacture and research rather than for those of large-scale management, and on his own insistence he was relieved of the presidential responsibilities. He became vice-chairman of the Board in 1930, acting in a special advisory capacity on all major Company developments. This work brought him back in such close contact with the laboratory he had founded that it was soon found desirable for him to head that organization again, and so in 1937 he became the director of research of the Corning Glass Works. This position he now holds, in addition to being vice-chairman of the Board of Directors.

Dr. Sullivan is also a member of the Board of Directors of L'Electro-Refractaire, the Corhart Refractories Company, the Corning Realty Corporation, the Pittsburgh-Corning Corporation, and the Steuben Securities Corporation.

In addition to the honorary Sc.D. degree from the University of Michigan, in 1933, his productive work has brought to him, jointly with W. C. Taylor, the Howard N. Potts Medal of the Franklin Institute, which he received in 1928. In 1929, he was given the Perkin Medal "For Distinguished Service to Applied Chemistry," and in 1940 he was one of the recipients of the awards given to the "Pioneers of Industrial Research."

Dr. Sullivan is a member of the leading scientific societies in this country and abroad. He is the author of many papers on geological subjects, physical chemistry, and glass, and he has been granted many patents on glass compositions, glass articles, and processes.

These statistical records of accomplishment, however, do no more than briefly intimate the actual record of achievement of a man who has been truly a scientific pioneer. The record of Dr. Sullivan is almost the progress record of an entire industry.

First Corning Laboratory

The story of Dr. Sullivan's first association with the Corning Glass Works illustrates well the state of science as applied to glassmaking at that time. The manufacturing manager of the Company had in his possession a glass-batch formula which was guarded with the greatest of secrecy. This one glass was used for many things; it was considered in fact to be the universal glass and consequently the major stock-in-trade of the Company. One of the foremost scientists in the country was a close personal friend of this official and, in discussing the situation with the glass manufacturer, amusedly told him that his formula was no more of a secret formula than a good analytical chemist allowed it to be. The glass man was astonished at this information but was wise enough to foresee that a science which could break down his secret formula could in turn develop new and far better ones. That interview led eventually to Dr. Sullivan's coming to Corning and to the formation of the first American glass research laboratory.

The first Corning laboratory was set up in a corner of the fourth floor of a factory building and occupied a space of about 1200 square feet. Dr. Sullivan's staff consisted of two trained men and several assistants. In 1914, the laboratory was moved to a new site and enlarged to about 5440 square feet. This space also was outgrown rapidly, and the work was distributed here and there throughout

the factory domain wherever a corner could be found and preempted. Today Dr. Sullivan is just completing his third glass laboratory building, an addition of a four-story building of 34,300 square feet, making a total of 61,430 square feet. The technical staff consists of one hundred and ninety glass scientists, engineers, and glass technologists. This staff and equipment are due largely to the initiative and creative ability of Dr. Sullivan.

Thirty-two years ago, scientifically planned and directed research in glass was unknown. To Dr. Sullivan, just entering this field, there was almost no background to draw on. The tools of research as applied to glass had to be developed, more precise analytical methods worked out, and limitations of many processes determined. Practical methods of check, control, and test had to be devised before progress could be made. There was nothing available for Dr. Sullivan to draw on except the fundamentals of a sound scientific training and the experiences of other arts. This in no way deterred him, but the possibilities of virgin fields proved intriguing to him, just as have undiscovered territories to other explorers. His first efforts therefore were directed necessarily toward building the essential foundations for a science of glass technology.

Reflecting perhaps the experience of these earlier years and his successful solution of the initial problems, Dr. Sullivan is a protagonist of sound fundamental training in science and proved research ability, as contrasted with specialized technological courses of education.

The most difficult achievements are not always those most evident and apparent. Dr. Sullivan's prime problem was that of the development of glasses for special technological uses, possibly to introduce glass into fields not hitherto occupied by glass or to make better or cheaper something attempted by another material. Often, too, there was the problem of making better glasses where better glasses were needed. There have been thousands of such glasses made and used. The Corning Glass Works, for example, now melts annually on a commercial scale two hundred and seventy-eight kinds of glasses, most of which serve a specific purpose not possible to any other material.

Low-Expansion Glasses

The most significant success attained by the Corning Laboratory has been in the field of low-expansion glasses of great chemical stability, one of which is the Pyrex-brand chemical-resistant glass used largely in chemical glassware and household utensils. Paralleling this development and almost of equal importance, though not so widely known, was the work on low-expansion glass for signal colors. Because of this work, American signal glassware today stands far ahead of all other signal glass in the world.

Dr. Sullivan is not only a highly trained chemist but has of necessity acquired specialized knowledge of the other sciences. It is a significant fact that his laboratory, first called a chemical laboratory, now contains not only more trained physicists on its staff than it does chemists, but its percentage of physicists is higher than that of any other industrial laboratory in this country and probably in the world.

The work of the Corning Glass Works laboratory has not all been directed toward definite development ends. Dr. Sullivan has realized fully the necessity for basic research as well. This policy has led to the publication by members of the laboratory staff of more than one hundred and fifteen papers in the scientific and engineering journals of this country and abroad.

Dr. Sullivan is modest, quiet, and unassuming, not overly talkative, but very direct in his approach. He sticks closely to the subject and is especially able at crystallizing a discussion to its logical conclusion. He has retained the greater portion of the physical vigor of his early years, and time has made little inroad on his appearance.

The glass industry is particularly fortunate in possessing a man who has combined the attributes of a trained analytical investigator, a scientist, and an executive. Such a man knows what should be done, how to do it, and how to go about getting it done.

Eugene C. Sullivan's honors were unsought but well earned. His responsibilities, even when forced upon him, were fully accepted and his achievements were inevitable.

HISTORY OF MILL-ADDITION OPACIFIERS IN VITREOUS ENAMELING*

By H. D. Prior

I. Introduction

The art of enameling on metal is an ancient one. Beautiful specimens of enameling have been found dating back thousands of years before the Christian Era. Until the middle of the eighteenth century, enamel was used only for decorative purposes. The first work in producing a usable article was done on cast iron. As far back as 1764, a Württemburg plant made useful, acid-resistant, chemical ware and cooking utensils.[1] Between the years 1764 and 1825, a number of enameling plants appeared in central and northern Europe and in the British Isles, but not until 1825 was any real progress made. Clarke Brothers made the first really utilitarian enamelware in England in 1825, consisting of cast-iron cooking utensils. This ware was more like a fused glass of low opacity[2] than an enamel.

II. First Mill-Addition Opacifier

Sheet-iron enameling was suggested as far back as 1790, but no sheet-iron ware was produced commercially[1] until 1835. Large-scale production of sheet-iron enamels started in about 1885 with the general introduction of stamped metal.[2] In the early nineties, tin oxide began to be used as a mill-addition opacifier. The use of cryolite was also introduced at about this time. From 1850, when ground frit and clay mill addition was generally known, and until 1885, no record of a mill-addition opacifier other than clay could be found by the writer. Following the introduction of sheet-steel enameling in or around 1890, no important change in the industry took place until 1906 except that the sheet-iron and cast-iron enameling industries were becoming separate industries.[3]

Compositions were guarded with great secrecy, but it is known that the development of opacity was becoming important in about 1850. Melt additions of tin oxide were used to promote opacity, and some enamels contained as high as 37% of tin oxide. Even then the enamels were little better than translucent until a mill addition of tin oxide was introduced.

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* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 11, 1940 (Enamel Division). Received April 2, 1940.

[1] Richard Aldinger, "Historical Development of Enameling Technique," *"Glashütte,* **68** [22] 373–75; [23] 390–91 (1938); *Ceram. Abs.*, **18** [6] 149 (1939).

[2] H. F. Staley, "Manufacture of Enameled Iron Sanitary Ware," *Trans. Amer. Ceram. Soc.*, **8**, 172–79 (1906).

III. Trend Toward Tin Oxide Replacement

The first real scientific work in enamel compositions was published between the years 1900 and 1914. Secrecy began to dwindle, but this age-old tradition was hard to remove. One of the most important problems was to replace the expensive tin oxide opacifier. Most of the work between 1900 and 1910 was on compositions in which tin oxide was still the standard mill addition. Between 1908 and 1914, much literature was published on substitute opacifiers. Fluorine compounds began to be appreciated as strong auxiliary opacifiers. Work was done with antimony and zirconia substitutes, and successful compositions were made, but they were not used extensively. Antimony, in many cases, was avoided because of its poisonous properties. Zirconium compounds were prohibited because of their high cost and because a uniform product was not available.

An enamel was developed in 1909 by Hartman,[3] in which 8% of ZrO_2 was used in the frit and 6% in the mill addition. It was predicted at this time that zirconium enamels would never be efficient because the cost of such a high amount would be prohibitive. Hartman found that more zirconia (of the type he used) was needed to replace the usual amounts of tin oxide and that zirconium borate was an excellent opacifier, and he suggested the use of ZrO_2 in light ground-coat enamels because of the difficulty in its reduction. He said that the use of a ground coat was to prevent the reduction of tin oxide. A number of patents was issued at this time on opacifying and clouding agents of various compositions, some containing antimony or antimonates and other zirconium compounds. Work was also done with titanium dioxide, but it did not promote much interest at the time.

From 1914 until the close of the war in 1918, there was intensive research for materials to replace tin oxide concomitant with the increase in price of this product. A typical compound introduced was an impure zirconium oxide which was said to replace tin oxide in the same amounts and manner. It was made from zirconium silicate by an alkali-fusion process and had the following approximate composition: ZrO_2 83%, TiO_2 4%, SiO_2 9%, Na_2O 2%, and the remainder combined water.[4] A rather popular antimony compound was also marketed at this time which consisted of 10 parts of china clay and 90 parts of sodium antimonate and was known as Leukonin. The general consensus by this time was that antimonates were nontoxic, but that antimony oxide should be avoided in enamels.

Landrum[5] has done work in commercial white cover coats, in which he used varying mill additions of tin oxide, ranging from 0 to 12%. He found that the best opacifying results were obtained by the mill addition and that the primary purpose of tin oxide in the frit was for the gloss that it imparted. This discovery accented the importance of the mill-addition opacifiers.

Increasing technical ability in the industry began to show more important gains in the enamel field. The major portion of the work in enameling research, however, was in frit compositions. The price of tin in 1918 was acute; tin oxide was selling for 72 cents per pound; antimony oxide could be purchased for 16 cents per pound. Shaw[6] made the following suggestions for the use of antimony oxide: (1) use only the purest, white antimony oxide, (2) use less than 5% of fluorspar, (3) maintain oxidizing conditions, (4) control color with ferric oxide, manganese oxide, and lead oxide, and (5) use less than 5% of cryolite. It was still chiefly a question of melt-addition replacement, and extreme care had to be used.

Literature was presented at this time by Landrum and Frost[7] on the use of titanium dioxide in enamels; this dioxide, also used as a frit addition, showed promise. Zirconium oxide opacifiers were not used to any extent because a pure product of proper physical characteristics and in a justifiable price range was not available. Zirconia base, mill-addition opacifiers were introduced, however, which were added to the mill with substances that precipitated colloids, such as NH_4Cl and $MgSO_4$.[8] These apparently were not accepted readily. Literature published during this period showed that zirconia and zirconium compounds offered great promise as substitutes for tin oxide.

Wet-process, cast-iron enameling in 1922 was becoming important.[9] The standard mill addition was 8% of tin oxide. Antimony compounds, especially sodium antimonate, had been used in dry-process enamels since 1910, and in 1923 large amounts of it were being used even though its value was still questionable. In 1923, the Bureau of Standards studied the effect of substitute opacifiers was well as some other compounds to replace tin oxide. The literature on the results of mill-addition studies showed the effects of tin oxide, sodium antimonate, titanium oxide, magnesium oxide, zinc oxide, zinc aluminate, and of the commercial substitutes, zirconium oxide and zirconium silicate. The general conclusion was that zirconium oxide and sodium antimonate were the best substitutes and ranked close to tin oxide. Next in order was zirconium silicate, but its purity was an essential requirement.[10] The first uniform zirconium oxide opacifier was made available at this time in quantities and at prices to make its use economically advisable. This product was introduced as tin oxide replacement, pound for pound, in cast irons both in wet and dry processes.

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[3] John Hartman, "Fishscaling of Sheet-Iron Enamels," p. 148. Enamel Bibliography and Abstracts, The American Ceramic Society, Columbus, Ohio, 1929.

[4] F. Haber, "Zirconium Oxide Replaces Stannic Oxide in Enamel Industry," *ibid.*, p. 141.

[5] R. D. Landrum, "Comparison of Ten White Enamels for Sheet Steel," *Trans. Amer. Ceram. Soc.*, **14**, 489–509 (1912).

[6] J. B. Shaw, "Antimony Oxide as an Opacifier in Cast-Iron Enamels," *Jour. Amer. Ceram. Soc.*, **1** [7] 502–13 (1918).

[7] R. D. Landrum and L. J. Frost, "Titanium Enamels," *ibid.*, **3** [4] 317–21 (1920).

[8] H. Kretzer and A. Cappel, "Opaque Enamels," U. S. Pat. 1,239,112, Sept. 4, 1917; Enamel Bibliography, p. 182.

[9] R. R. Danielson and H. P. Reinecker, "Wet-Process Enamels for Cast Iron," *Jour. Amer. Ceram. Soc.*, **5** [10] 647–69 (1922).

[10] R. R. Danielson and M. K. Frehafer, "Effect of Some Substitutes for Tin Oxide on Opacity of White Enamels for Sheet Steel," *ibid.*, **6** [5] 634–44 (1923).

IV. ZrO_2 Replacing Tin Oxide in Mill Additions

In 1924, Kinzie[11] gave the following conclusions on results relative to development of ZrO_2 as an opacifying agent in vitreous enameling: ZrO_2 to replace SnO_2 (1) must have a high degree of purity, (2) must inherit from the process, incidental to its production, a certain physical structure conducive to producing maximum opacity in enamels, and (3) must be suited to the enamel composition because comparative opaquing strength varies with the composition. He also stated that this product could replace SnO_2 in wet-process cast iron, in dry-process cast iron, and in mill additions in sheet-steel enamels to give high opacity, luster, and suitable color. This product was known as Opax.

In 1924, Wolfram[12] studied the effect of zirconia in sheet-steel enamels wherein he covered both the melt and the mill-addition replacements of tin oxide and its effect on thermal shock and on impact and acid resistance. He found that increased zirconia increases impact resistance when used either in enamel or mill addition. When zirconia was used in the melt of cover coats, it had little or no effect on the thermal-shock resistance, but in each case of mill addition a decided increase in thermal-shock resistance was obtained. No benefit was obtained in acid resistance when zirconia was added to the melt, but in every case in which zirconia was added to the mill, some benefit over tin oxide was obtained. Interesting results were found on opacity. Wolfram observed that a 4% mill addition of zirconia to replace 7% of tin oxide gave an enamel as white as SnO_2 although it lacked covering power. By replacing 7% of tin oxide with 8% of zirconia, an enamel was obtained equally as white as when tin oxide was used with equal or better opacity. Wenning[13] offered the following conclusions on the use of pure zirconium oxide as a mill-addition opacifier: (1) the fish-scaling tendency was reduced and crazing was overcome in one enamel; (2) in some sheet-steel enamels wherein pure ZrO_2 replaced SnO_2, the whiteness and opacity approached closely that of tin oxide; (3) in a mill formula of low fluoride enamels, it increased the acid resistance; (4) ZrO_2 was not affected by reducing furnace heat; and (5) it was more resistant to thermal and mechanical shock. Wenning's studies aroused considerable interest. It seemed to be proved definitely that zirconium oxide could replace tin oxide at the mill; and from this time, both zirconia-base and antimony-base mill-addition opacifiers began to increase their foothold throughout the enameling industry.

Several new phases in the industry had developed by this time. Frit companies were well established. There was strong competition, however, and attempts were made to develop better and cheaper enamels. The result was the introduction of antimony whites.

Opacifier companies were becoming known. Those producing zirconia-base opacifiers were forced to develop frit compositions that would show their opacifiers to the best advantage, and opacifier companies producing antimony-base opacifiers were familiar with the antimony white frits. Zircon enamels were developed which led the way for one-coat whites. Antimony frits were designed to use zirconium oxide opacity most advantageously.

Studies to find substitutes for tin oxide were not confined to the United States. Literature published by Lai[14] in 1927 showed that it was highly desirable to replace tin oxide in enamelware made in China. His conclusions, drawn from research on kitchenware enamels, were that zirconium oxide and sodium antimonate gave the best results and were nearly as good as tin oxide itself. Zirconium oxide, especially, increased resistance to thermal shock and acids. Sodium antimonate increased impact resistance. In Germany, Malinovszky[15] stated that in a cast-iron enamel, with zirconia as the opacifier, the best acid resistance was obtained.

V. Work of Various Authors with Mill-Addition Opacifiers

Andrews[16] did some interesting work in 1928 on control of opacity, in which he studied the effects of varying amounts of tin oxide at the mill. He concluded that (1) the use of up to 20% of tin oxide increases opacity; (2) the rate of opacity decreases as the total amount of tin oxide increases; (3) addition of over 10% of tin oxide adds little opacity; (4) if less than 10% is used, auxiliary opacifiers aid opacity, the optimum of tin oxide being between 5 and 10%; and (5) enamels using tin have a good white color with a bluish tint. In his work on the development of acid-resisting, white sheet steels, Andrews[17] found that zirconium oxide (Opax) was a good mill addition and that neither tin oxide nor zirconium oxide decreased resistance when they were added at the mill. Zirconium oxide tended to increase acid resistance when it was added at the melt but it did not improve opacity.

Pearce and King[18] studied the effect of fluorides as mill-addition opacifiers, but negative results were obtained. Research by Kinzie and Plunkett[19] at this time showed that the increasing of mill-addition opacifiers had little effect on cross-breaking strength of enamel.

In 1931, Vielhaber[20] studied the action of mixtures of several mill-addition opacifiers. His conclusions were that the strength of every opacifier has a limit over which opacity ceases to increase perceptibly, but if two opacifiers are combined, opacification continues to increase.

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[11] C. J. Kinzie, "Results of Certain Researches Relative to Development and Use of Zirconium Oxide Products as Opacifying Agents in Vitreous Enameling Processes." Enamel Bibliography, p. 173.

[12] H. G. Wolfram, "Effect of Zirconia in Enamels for Sheet Steel," *Jour. Amer. Ceram. Soc.*, **7** [1] 1–13 (1924).

[13] W. F. Wenning, "Zirconia in Sheet-Iron Enamels," *Bull. Amer. Ceram. Soc.*, **2** [5] 102–104 (1923).

[14] Chi-Fang Lai, "Sheet-Steel Cooking-Ware White Enamels Economically Suitable for Use in China," *Jour. Amer. Ceram. Soc.*, **10** [3] 150–62 (1927).

[15] A. Malinovszky, "Acid-Resistant Enamels," *ibid.*, **11** [2] 110–13 (1928).

[16] A. I. Andrews, "Control of Opacity of Enamels," *Ceram. Ind.*, **11** [3] 266–67 (1928); *Ceram. Abs.*, **7** [11] 745 (1928).

[17] A. I. Andrews, "Development of Acid-Resisting White Sheet-Steel Enamels," *Jour. Amer. Ceram. Soc.*, **13** [6] 411–26 (1930).

[18] R. M. Pearce and R. M. King, "Opacifying Effect of Fluorides in Enamel Mill Additions," *ibid.*, **13** [4] 272–76 (1930).

[19] C. J. Kinzie and J. A. Plunkett, "Use of Lindemann-Danielson Cross-Bending Test Machine," *ibid.*, **13** [9] 664–68 (1930); p. 666.

[20] L. Vielhaber, "Action of a Mixture of Several Opacifiers," *Emaillewaren-Ind.*, **8** [12] 90–91 (1931); *Ceram. Abs.*, **10** [8] 547 (1931).

To prove this theory, a cast-iron plant in Germany added three opacifiers, consisting of tin oxide, Leukonin, and Terrar, a zirconium compound.

The trend in 1932, as frits became more opaque, was to get thinner coatings of enamels. The literature published concerning this problem of opacity versus thickness showed that in one enamel a 125% increase in thickness was required to give a 27% increase in opacity. It was also shown that, by increasing the opacifier from 4 to 8%, the thickness necessary to give a reflectance factor of 70 was decreased from 0.0167 to 0.0106 in.[21] This helped to decrease the thickness of enamel coatings and still maintain the necessary opacity.

During all of this development work, research was attacked from two sides: one was fundamental, theoretical research, and the other, practical, industrial research. In the field of theoretical research, Andrews and his coworkers[22] used X-ray studies to determine the effect of opacifiers in enamels. This was done from the standpoint of mill-addition and enamel-addition opacifiers in white cast-iron and white sheet-steel enamels. The results of this excellent piece of work showed that all mill-addition opacifiers existed as added in the enamels in the crystalline form. Zirconium oxide was an exception and existed as some unidentified compound. The theory in explaining this phenomenon was that the ZrO_2 reacts with the glass and forms small globules of zirconium glass of high index of refraction. As they are not very soluble or miscible in the enamel glass, they may be retained as such, giving the opacity contributed to the enamel by zirconium additions.[22] The question of gas opacity has risen from time to time from the theoretical standpoint, and by 1932 it was a well-established and accepted fact that opacity in enamel was obtained by the formation of minute bubbles in the enamel resulting from the liberation of adsorbed or combined gases in the constituents. Many methods have been offered to introduce gas-forming opacifiers in mill additions, but these were unsuccessful because of the lack of scratch resistance and the difficulty in controlling the bubble size. A gas opacifier to work successfully would have to be made under carefully controlled and reproducible conditions, and firing conditions would also have to be carefully controlled.

VI. Finely Milled Enamels

Another angle was attacked during 1934 and 1935 to produce thinner enamel coatings. Porter and Holscher[23] studied the effect of fine milling of enamels. Research on this problem had been done as far back as 1922. In a definite study on the effect of fine milling, variations were made of 12 to 0% plus 325-mesh. General results indicated that fine milling would (1) give higher opacity, (2) decrease by 25% the amount of enamel needed, (3) give less wear on spray guns and better suspension, and (4) result in lower firing temperatures. The chief objection was that careful handling was needed to prevent tearing and starring.[23] Too thin coatings, furthermore, could not be applied because of spray pattern. These studies however, did not go far enough; 6% of tin oxide was used at the mill, but higher mill additions were not tried. Because of spray pattern, thin coatings could not be applied to show worth-while savings. Perhaps the reason for not trying higher mill additions was that, with the introduction of superopaque enamel frits, the general inclination in the enameling industry from the period of 1934 was to use lower amounts of mill-addition opacifiers. Another reason that further work was not continued was because of the studies of Bryant and Porter[24] on the effect of mill additions in finely milled enamels in 1935. Their conclusions were that (1) fine grinding increased opacity in some enamels but not greatly in others, (2) addition of tin oxide up to 6% increased opacity, but beyond that its value was doubtful, (3) introduction of substitutes in mill additions in some cases produced as much opacity as tin oxide, depending entirely on frit composition, and (4) by the addition of two opacifying agents to the mill, it was possible to overcome the saturation point of 6% of tin oxide.

Many of the substitute opacifiers on the market not only replaced tin oxide, but in many cases the properties of these were such that they equaled or surpassed tin oxide in luster, covering power, and opacity. They excelled tin oxide in some respects, owing to the properties they imparted to the enamel.

By 1938, tin oxide was no longer considered to be the universal mill-addition opacifier. In fact, by far the greater percentage of mill-addition opacifiers used in the industry are tin oxide substitutes. The opacifier companies, through diligent research, seemed to have done a good job in solving the age-old problem of replacing tin oxide at the mill. With the ever-changing world, research still goes on and studies on mill-addition opacifiers continue with the trend toward better and cheaper enamels. Andrews and King[25] have presented the results of a microscopic study of the mechanism of mill-added opacifiers. Their observations indicated that the mill-added opacifiers function principally as layers between the frit particles and do not diffuse well into the enamel. This explains why (1) mill-added opacifiers do not continue to increase reflectance when they are added in large quantities (this is true unless the enamel is ground extremely fine), (2) increased fineness of milling and extreme fineness of opacifiers aid reflectance, and (3) transparent, glassy frits appear mottled when mill-added opacifiers are used. The conclusion from these observations was that increased reflectance of enamels originates in the frit or is brought about either by finer milling or by better diffusion of the mill-added opacifiers.

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[21] "Enamel Opacity," *Ceram. Ind.*, **18** [6] 471–72 (1931); *Ceram. Abs.*, **11** [2] 83 (1932).

[22] (*a*) A. I. Andrews and J. P. Breen, "X-Ray Investigation of Opacifying Compounds Present in Sheet-Iron Cover Enamels," *Jour. Amer. Ceram. Soc.*, **16** [7] 325–27 (1933).

(*b*) A. I. Andrews, G. L. Clark, and H. W. Alexander, "Determination by X-Ray Methods of Crystalline Compounds Causing Opacity in Enamels," *ibid.*, **16** [8] 385–92 (1933).

[23] F. R. Porter and H. H. Holscher, "Use of Finely Milled Enamel Slips," *ibid.*, **18** [2] 39–42 (1935).

[24] G. L. Bryant and F. R. Porter, "Effect of Mill Practice and Mill Additions on Opacity of Enamels," *ibid.*, **19** [2] 55–59 (1936).

[25] A. I. Andrews and B. W. King, Jr., "Mechanism of Mill-Added Opacity in Porcelain Enamels," *ibid.*, **22** [6] 173–76 (1939).

The fine-milling question again arose, and this time several improvements and modifications accompanied it. The research laboratories of the Titanium Alloy Manufacturing Company had worked with fine milling and high opacifier additions as far back as 1929. But they had met with the same difficulties as others, namely, spray pattern, tearing and crawling, and bad results because of poor ground coats. Since then, spray guns have been developed that give atomization which enables uniform coatings to be applied as low as 25 gm. per sq. ft. Early in 1938, this idea was again brought to the attention of the enameling industry. Milling went as far as 1% on 325-mesh. High mill additions were made, originally 20%, which dropped back to about 12%. Successful commercial trials were made and many of the "bugs" were ironed out. Sodium-nitrite mill addition was found to give better dry strength and to reduce crawling or tearing tendencies. The addition of opacifiers during the late stages of milling cut the milling costs. It was thought that brushing could be eliminated, but it has been discovered that until ground-coat beading can be eliminated this will not work. The advantages of thinner applications are (1) less enamel is processed per foot of coverage, (2) the enamel is more serviceable from the standpoint of chipping and cracking under flexure and there is less warpage, (3) high gloss and less scumming, (4) more reclaims, and (5) higher saving in costs. Owing chiefly to ground-coat difficulties in many plants, the fineness was gradually raised to 0% on 200-mesh. The present trend is to use a superopaque frit milled to 0% on 200-mesh (about 9 grams on 325-mesh) and to use from 8 to 12% of mill addition. A coating of about 40 gm. per sq. ft. is applied as compared to the old 72 gm. per sq. ft. There are some plants, however, using normal opaque frits with 6 to 8% of mill addition; others are using superopaque frits with 2 to 4% of mill addition.

VII. Cerium Compounds

In recent years, cerium compounds have been used (especially in Germany) with some success as mill-added opacifiers. These have not as yet received much attention or study in this country. At the present time, there are two general types of mill-addition replacements for tin oxide. One is an antimony-base and the other a zirconium-base opacifier. The latter type is offered to the industry in many versatile forms designed to meet all special requirements.

VIII. Conclusions

In the early days when frits lacked high opacity, the mill addition was chiefly tin oxide varying from 8 to 12%. Then as the normal opaque frits appeared, mill-addition opacifiers dropped usually to 6%, and the tin oxide gradually was replaced with substitute opacifiers. In later years, superopaque enamel frits came into prominence whereby mill additions as low as 2% were used successfully at a normal fineness of 10 to 12 gm. on 200-mesh. More recently, the fine-milled, high opacifier mill addition and lightweight application has come into use. The present trend seems to be swinging definitely toward this idea and with still lighter coats the aim.

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Whitesell, Buhel E., Saltsburg, Pa.
Whitesell, Robert J., 5033 Saul St., Philadelphia, Pa.
*Whitford, W. G., School of Education, Box 20, Univ. of Chicago, Chicago, Ill.
Whitmer, J. D., Sparta Ceramic Co., East Sparta, Ohio
Whittaker, Harry, Research Labs., Crane Co., 4100 S. Kedzie Ave., Chicago, Ill.
*Whittemore, J. W., Virginia Polytechnic Inst., Blacksburg, Va.
Whittemore, O. J., Box 603, Fort Dodge, Iowa
Whittemore, O. J., Jr. (Student), 1020 Third Ave., South, Fort Dodge, Iowa
Whittington, Lloyd R., Box 122, Fredericksburg, Ohio
Whitwood, Robert A. (Student), Lambda Chi Alpha, Alfred, N. Y.
Widemann, R. V., F Rue Eugene Labiche, Paris 16e, France
Wilcox, Herman G., 764 Montclair St., Pittsburgh, Pa.
Wildblood, Norman R., Blythe Colour Works, Ltd., Cresswell, Stoke-on-Trent, England
*Wilkes, Gordon B., Massachusetts Inst. of Tech., Cambridge, Mass.
Willach, Heinrich, Krauschwitz, Oberlausitz, Germany
Williams, Arthur E., 1218 5th St., Moundsville, W. Va.
Williams, Clyde E., Battelle Memorial Inst., 505 King Ave., Columbus, Ohio
Williams, Francis J., National Lead Co., Research Labs., 105 York St., Brooklyn, N. Y.
Williams, John A., Box 250, Trenton, N. J.
Williams, Joseph S., P. R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis, Ind.
Williams, Robert A., Franklin Tile Co., Lansdale, Pa.
Willis, James B., 2905 N. Charles St., Baltimore, Md.
Wilson, Ashley F., 591 Ferry St., Newark, N. J.
Wilson, Earl O., Yenching Univ., 150 Fifth Ave., New York, N. Y.
Wilson, George, Glenmoor, East Liverpool, Ohio
*Wilson, Hewitt, Electrotechnical Lab., United States Bureau of Mines, Norris, Tenn.
Winburn, H. L., Box 35, Pulaski Heights Sta., Little Rock, Ark.
Windsor, Benjamin R., 410 N. Main St., Abingdon, Ill.
Winkelmann, F., Irish Glass Bottle Co., Ltd., Charlotte Quay, Dublin, Ireland
Winship, William W., 12 East 46th St., New York, N. Y.
Winters, F. T., Pacific Coast Borax Co., 51 Madison Ave., New York, N. Y.
Wisconsin Porcelain Co. (L. A. Stohl), Sun Prairie, Wis.
Wiseman, Claude F., West Virginia Brick Co., Charleston, W. Va
Wishart, L., Vereeniging Brick & Tile Co., Ltd , Box 49, Vereeniging, Transvaal, South Africa
Wishoski, I. Stanley, 1101 Union Trust Bldg., Pittsburgh, Pa.
Wiss, J. E., 1339 Lincoln Rd., Columbus, Ohio
Witherow, Charles N., Berwindale, Clearfield County, Pa.
Witschey, R. A., A. P. Green Fire Brick Co., Mexico, Mo.
Witzemann, Albert W. (Student), 101 W. Lakeview Ave., Columbus, Ohio
Wolfensberger, Robert E., 648 Main St., Bethlehem, Pa.
*Wolfram, H. G., Porcelain Enamel & Manufacturing Co., Baltimore, Md.

Wong, Y. Y., 11 Tytam Village, Stanley, Hong Kong, China
Wood, Wallace B., Wallace China Co., Ltd., Box 47, Huntington Park, Calif.
Woodruff, Ernest W., 219 E. North Water St., Chicago, Ill.
Woodruff, Robert W., Box 373, Oakfield, N. Y.
Woods, William J., Box 627, Lewistown, Pa.
*Worcester, W. G., Dept. of Ceramics, Univ. of Saskatchewan, Saskatoon, Saskatchewan, Canada
Work, Harold K., Jones & Laughlin Research Lab., 40 Longworth St., Pittsburgh, Pa.
Work, Lincoln T., Metal & Thermit Corp., Carteret, N. J.
Wortley, G. W., R. & A. Main, Ltd., Gothic Works, Falkirk, Scotland
Wright, Ann T., 121 Clifton Ave., Minneapolis, Minn.
Wright, Daniel K., Incandescent Lamp Dept., General Electric Co., Nela Park, Cleveland, Ohio
Wright, Edward P., 313 West 6th St., East Liverpool, Ohio
Wright, George C., 3467 Clearfield Ave , Pittsburgh, Pa.
Wright, J. W., 1129 Warren St., Alton, Ill.
Wygant, James F. (Student), Lambda Chi Alpha, Alfred, N. Y.
Wysong, Charles F., Georgia School, Tech., Ceramic Engr. Dept., Atlanta, Ga.
Wysor, D. C., General Chemical Co., 40 Rector St., New York, N. Y.

Yanovsky, Alexander, 13 Izola Ave., Fords, N. J.
Yarte, Andrew A., Troqueles y Esmaltes, Apartado 371, Monterrey, N. L., Mexico
Young, David H., Georgia Kaolin Co., Dry Branch, Ga.
Young, Willard G., 206 N. Jefferson St., Robinson, Ill.
Youngstown Arc Engraving Co. (W. J. Gutknecht), Vindicator Bldg., Youngstown, Ohio
Yount, Richard V., Box 435, Oakmont, Pa.

Zabawsky, Zeno (Student), Alfred Univ., Alfred, N. Y.
Zapfe, Richard C., Pomona Tile Co., Pomona, Calif.
Zapffe, Carl A., Battelle Memorial Inst., 505 King Ave., Columbus, Ohio
Zapp, Friedrich, Fischern near Karlsbad, Germany
Zarbo, George, Fenimore St. near Second, Vineland, N. J.
Zehm, Robert C., Joseph Dixon Crucible Co., Jersey City, N. J.
Zeiller, Irwin F., B. F. Drakenfeld & Co., Inc., 45–47 Park Place, New York, N. Y.
Zeiller, Oscar F., 42–38 204th St., Bayside, L. I., N. Y.
Zerfoss, Samuel (Student), 215 Mineral Industries Bldg., State College, Pa.
Zimmer, Daniel B., 1381 Sedgwick Ave., New York, N. Y.
Zimmer, David C., Patterson Refractories Co., East Liverpool, Ohio
Zimmerman, K., Rijkskleischool, Lange Tiendeweg 79, Gouda, Holland
Zink, George H. (Student), 204 Ceramics Bldg., Univ. of Illinois, Urbana, Ill.
Zinszer, William K., Ames Pottery Co., Ames, Iowa
Zopfi, Albert S., 1143 River Rd., Maumee, Ohio
Zurer, Raymond R., Box 84, Alfred, N. Y.
Zvanut, Frank J., Ferro Enamel Corp., 4150 East 56th St., Cleveland, Ohio
Zwermann, Carl H., Univ. of Washington, Seattle, Wash.

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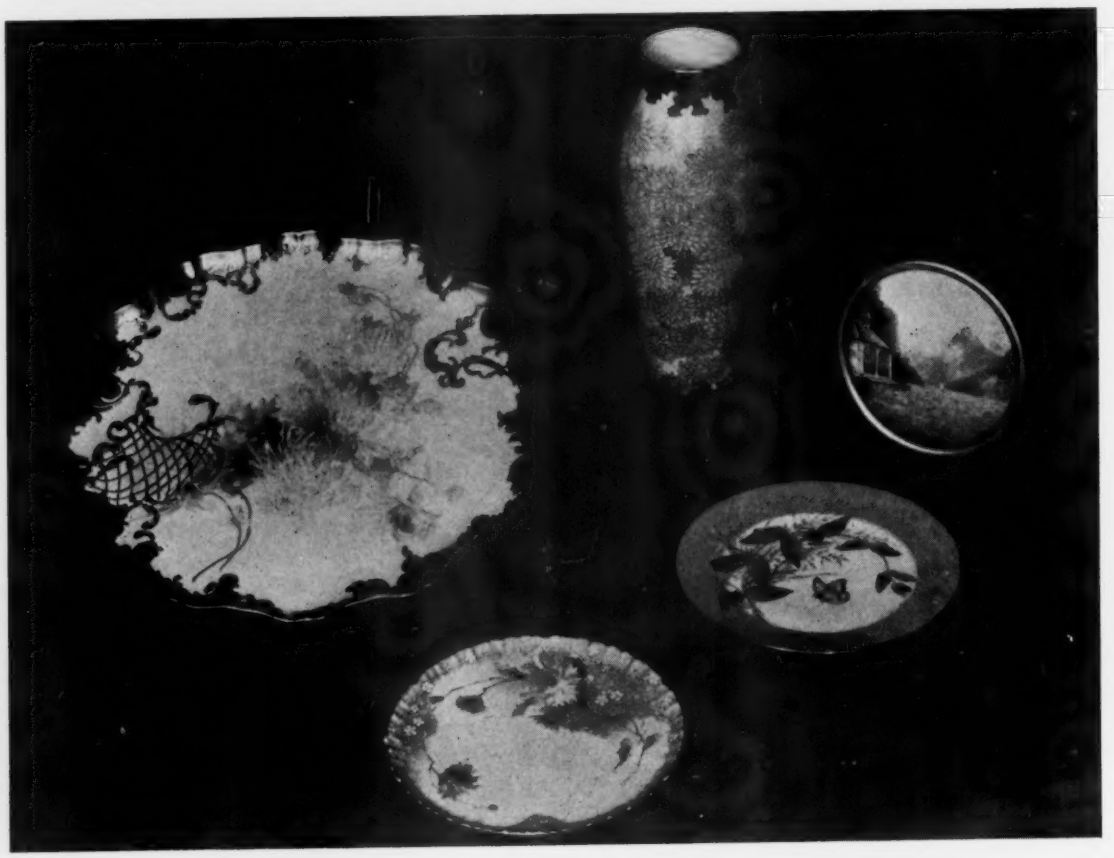
ACTIVITIES OF THE SOCIETY

Overbeck Pottery exhibit in The Society executive offices. The tall vases in the background were made by the late Elizabeth Overbeck, a Fellow of The Society.

Artware made by students of the Smith-Hughes Extension Course of West Virginia University, Charles R. Tennant, supervisor (see page 273, July, 1940, *Bulletin*).

All of the exhibits in the executive offices of The Society are being numbered and labeled as a permanent record for members of The Society.

Gifts to The American Ceramic Society by Members of the Porcelain League of Cincinnati



PORCELAIN LEAGUE EXHIBIT

Plate painted by M. Louise McLaughlin for Tenth Anniversary of the Pottery Club, 1889 (presented by Laura A. Fry).

Platter painted by Mrs. Mary Taylor Dominick (presented by her daughter, Helen Dominick).

Plate and three cups and saucers by Laura A. Fry (one set is the first presented to Porcelain League; one set presented by Anna Riis).

Cup and saucer and two small bowls by Anna Riis.

Cup and saucer by Mrs. Lillian Fry Fisher.

Overglaze decorated vase, 1893, Columbia Exposition, blue ribbon (painted and presented by Alice B. Holabird).

Plate painted by Julia H. Rice for Tenth Anniversary of the Pottery Club, 1889 (presented by Florence Murdoch).

Cup and saucer, small gold pitcher, plaque, and small gold cup and saucer by Mrs. W. H. Stanage.

Cup, saucer, and plate by Carrie Clemmer.

Three cups and saucers by Mrs. Abby Tyler Fields.

Cream pitcher by Helen Peachey.

Two cups and saucers by Mamie W. Chapman.

Cup and saucer by Clara Chipman Newton.

Large vase by Mrs. Walter Hunnewell Field (presented by Mrs. G. L. Hamilton).

Ceramic Art Group at Blue Ridge, July 29, 1940

CHICAGO SECTION

The officers of the Chicago Section have issued the schedule of meetings for the 1940–1941 season.

October 16–18

Fifth Annual Forum, Porcelain Enamel Institute, Univ. of Illinois, Urbana, Ill.

November 6

Invitation to be guests of the American Institute of Metallurgical Engineers to hear R. E. Brannon, Bakelite Corporation, speak on "Plastics" at the Chicago Lighting Institute, Civic Opera Bldg., Chicago, Ill.

February 7

Chicago Section meeting. Structural clay products, Charles Filippi, Illinois Brick Co., Chicago; new ceramic raw materials and discussion of electrolytes; 38th floor, Civic Opera Bldg., Chicago, Ill.

March 30–April 5

Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md.

May 16–17

Seventh Annual Glass Conference, Univ. of Illinois, Urbana, Ill.

June 14

Annual golf tournament.

The officers of the Section are as follows:

Chairman: ALBERT L. VODICKA, Aetna Porcelain Enameling Co., Chicago, Ill.

Vice-Chairman: RUDYARD PORTER, Carnegie-Illinois Steel Corp., Evanston, Ill.

Secretary-Treasurer: REXFORD NEWCOMB, JR., Industrial Publications, Inc., 59 East Van Buren St., Chicago, Ill.

(1940)

PACIFIC-NORTHWEST SECTION

Twenty-six members of the Pacific Northwest Clayworkers' Association and the Pacific-Northwest Section of The American Ceramic Society gathered at the Kilgard plant of the Clayburn Brick Company, Ltd., at 11:00 A.M., Friday, August 23. J. W. Ball, plant manager, guided the visitors through the factory. All of the interesting mechanical and firing equipment used in the manufacture of firebrick, refractories, sewer pipe, and face brick was carefully explained or demonstrated. J. H. Roaf, president of the Clayburn Company, was host to the visitors at a lunch served in one of the round downdraft kilns at the plant.

After lunch, the group drove to the Port Haney Brick Company, Ltd., Haney, B. C. E. G. Baynes, president of the Company, and James Hadgkiss, engineer, showed their method of making drain tile, hollow tile, and brick. Following the tour, a dinner meeting was held in the Grosvenor Hotel, Vancouver, B. C. Mr. Hadgkiss, president of the Section, introduced the speaker of the evening, Leslie J. Martin, director of Home Oil Distributors, Ltd., who recently organized the British Empire Air-Training Scheme in British Columbia. Mr. Martin spoke on "United States Aid to Canadian Aviation." Following the talk, members were called on for comments, after which the meeting adjourned for a general discussion and visit.

Saturday was spent in playing golf and viewing the sights of Vancouver and the surrounding countryside.

—CARL H. ZWERMANN, *Secretary*

PITTSBURGH SECTION

The Pittsburgh Section began its 1940–1941 season on September 20 with a Get-Together Harvest Festival at the "Vic-Nor" Farms in Butler County, Pa. A technical session was held following an afternoon of sports activities.

—GEORGE BAIR, *Secretary*

NEW MEMBERS FOR SEPTEMBER

Personal

CUSICK, ALBERT L., JR., 1233 Jewett Drive, Zanesville, Ohio; ceramic artist, Brush Pottery Co.

ELLIOTT, WILLIAM S., 6467 83rd Place, Rego Park, L. I., N. Y.; engineer of tests, New York City Department of Public Works.

*GRIGSBY, CHESTER E., General Refractories Co., 1600 Real Estate Trust Bldg., Philadelphia, Pa.

HEUSSNER, CARL E., 552 Brookside Drive, Birmingham, Mich.; Chrysler Corp.

NEIMAN, ROBERT, Whip-Mix Corp., Inc., 411 W. Avery Ave., Louisville, Ky.; director of research.

PETERSON, W. H., M. D. Valentine & Bro. Co., Woodbridge, N. J.; president.

PINOTTI, FRED D., 1010 New Pear St., Vineland, N. J.; assistant to chief engineer, Kimble Glass Co.

POPE, FRANK B., JR., 1804 Koppers Bldg., Pittsburgh, Pa.; sales engineer, Frank B. Pope Co.

STEWART, JACK, 5413 W. Washington Blvd., Los Angeles, Calif.; manager, DeLee Art Co.

Student

University of Illinois: *FLOYD BAILEY.
Rutgers University: WILLIAM L. PESKIN.

MEMBERSHIP WORKERS' RECORD

Personal

C. A. Freeman	3	H. M. Kraner	1
Donald Hagar	1	E. L. Maxson	1
E. L. Hettinger	1	Office	1
J. R. Hostetter	1		

Student

G. H. Brown	1	R. K. Hursh	1
		Grand Total	**11**

*Indicates former member of Society rejoining.

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Paid Membership Record

Date of Record	Members Paid		Deferred	Subscriptions	Monthly Sales	Total Circulation
	Personal	Corporation				
December 22, 1937	1713	220	12	523	220	2688
December 19, 1938	1815	222	26	589	220	2872
December 19, 1939	1876	237	27	642	220	3002
January 22, 1940	1930	244	23	656	220	3073
February 20, 1940	1972	243	30	669	220	3134
April 17, 1940	1724	241	30	522	220	2737
May 21, 1940	1801	247	27	552	220	2847
June 19, 1940	1839	251	28	556	220	2894
July 18, 1940	1870	254	32	561	220	2937
August 19, 1940	1885	254	31	565	220	2955
September 19, 1940	1892	255	28	572	220	2967

Only eighty more Personal members needed to make the all-time high of Paid Personals. Here is a Booster Offer.

New personal members enrolled after October 15 may elect to

(1) pay one-fourth annual fee or $3.13 and receive only the October, November, and December publications or

(2) pay the full $12.50 for 1940 membership and receive all of the 1940 publications or

(3) pay $12.50 and join as of 1941 and receive the December, 1940, issues (which include the indexes) as a bonus.

GEORGE MERZ WRITES FROM SWEDEN

37 Essinge Brogata
Stockholm, Sweden,
24, August, 1940

Sir:

As you probably know, I am since ten years a member of your Society. Up to September, 1939, I have worked as a laboratorium manager in the factory of Refractories Materials, Ltd., in Skawina, Poland. The war and the evacuation connected with it forced me to leave my work. Shortly afterward, I was engaged by the Magnesit Factory, Ltd., in Vlaardingen, Holland, as a technical adviser. The latest events in Holland kept me in Stockholm, where I was just on the way to my new place of destination, and thus I could not start on my new duties there.

I do not know whether exists an organisation at The American Ceramic Society whose task it is to help your members in similar circumstances. But my momentary really difficult situation authorizes me to turn to you for help and advice—the more because I am probably the only Polish member.

I am a chemical engineer. After finishing the technical university, I specialised in refractories with Prof. Dr. K. Endell and in the Tonindustrielaboratorium in Berlin. My work of ten years in Skawina gave me the opportunity to increase my knowledge of production as well as research methods of fire-clay, silica, and magnesit brick. In the last three years, I introduced magnesit brick production in Skawina, with the collaboration of our technical adviser, Ing. L. Litinsky.

I am Polish, thirty-four years old, Roman Catholic, and married. I speak Polish, French, English, and German. I turn to you with the great request to help me to find work. I think this should be easy to you with your international relations and connections. It is the same to me whatever country this would be as well as the conditions. I know my profession and am sure that I can be of good use in any factory of refractories.

Since I am out of touch with Poland, France, and Holland, I can state you as reference only the correspondence with the Dutch firm which engaged me. The references at my disposal in Sweden are the Polish Legation or Polish Consulat in Stockholm, Karlawägen, and the Swedish-Polish Chamber of Commerce in Stockholm, Regeringsgatan 22.

I hope you consider my difficult situation and that I shall get soon from you a favourable answer, if possible by Clipper.

Yours faithfully,
GEORGE MERZ

AUTUMN MEETINGS

Art: National Ceramic Exhibition, Syracuse, N. Y., October 12–November 4

Enamel: Porcelain Enamel Institute Forum, University of Illinois, October 16–18

Structural Clay Products Division with Structural Clay Products Institute: Hotel Roanoke, Roanoke, Va., November 12–14

Institute of Ceramic Engineers with A.I.M.M.E.: Urbana, Ill., November 14–15

ANNUAL MEETING OF THE CERAMIC ASSOCIATION OF NEW YORK

The annual meeting of the Ceramic Association of New York will be held at Alfred, N. Y., Friday, October 18, 1940.

FORTY-THIRD ANNUAL MEETING
March 30–April 5, 1940
For map of Baltimore, see page 30 of the Advertising Section

PROGRESS REPORT OF AMERICAN STANDARDS ASSOCIATION SECTIONAL COMMITTEE A-62

A comprehensive report constituting one hundred and fifty-six pages of drawings and text has been submitted to the members of the Sectional Committee A-62 on Coordination of Dimensions of Building Materials and Equipment. The letter of transmittal, dated September 4, 1940, states in part as follows:

"This Progress Report, issued under instructions of the Executive Committee, includes most of the studies that have been developed and reviewed by the first three study committees.

"The Progress Report is available for immediate trial use by architects and builders. The report presents illustrations of the application to a few important materials of the basis of coordination now being investigated by the Sectional Committee.

"Your suggestions and criticisms on this work are earnestly solicited. Please forward promptly any recommendations for changes that you may wish to have incorporated in the Report. It is hoped that the Committee can take action within a few months on the submittal of the substance of the Report in revised form to the A. S. A. for approval as American Standard."

—FREDERICK HEATH, JR., *Member representing The American Ceramic Society*

REPORT ON ACTIVITIES OF A.S.T.M. COMMITTEE C-14 ON GLASS AND GLASS PRODUCTS

Committees

At the Atlantic City meeting of the A.S.T.M., in June, 1940, election of officers was held for the next two years, and chairmen of subcommittees have been appointed. The present official roster is as follows:

Chairman, G. W. MOREY, Geophysical Lab., Washington, D. C.; *Vice-Chairman*, U. E. Bowes, Owens-Illinois Glass Co., Toledo, Ohio; *Secretary*, LOUIS NAVIAS, General Electric Co., Schenectady, N. Y.

Advisory Committee: This Committee is made up of the three officers plus four additional members, namely, J. C. HOSTETTER, G. F. JENKS, J. T. LITTLETON, and R. W. WAMPLER.

Chairmen of Subcommittees: The appointments are as follows:

I. Nomenclature and Definitions, F. C. FLINT
II. Chemical Analysis, G. E. F. LUNDELL
III. Chemical Properties, F. W. ADAMS
IV. Physical and Mechanical Properties, J. T. LITTLETON
V. Thermal Properties, E. W. TILLOTSON
VI. Glass Construction Block and Tile, J. P. STAPLES

Nomenclature and Definitions

The definition of glass is still a debatable subject. Some glass enthusiasts would like to limit the name to inorganic glasses. The infidels are willing to admit that the reversible types of organic resins have the features of a glass, namely, the continuous increase in fluidity with increasing temperature and the reverse with falling temperature.

Chemical Analysis

Plans are being considered for the adoption of "short methods" of analyzing glasses, which will include (1) the partition method for boron, (2) the Hicks' method for potassium, (3) the uranyl acetate method for sodium, and (4) the various 8-hydroxyquinoline methods. The chemical analyses of aluminum silicates may also be considered.

Dr. Lundell gave a report on the progress of his subcommittee at this meeting.

The Tentative Standard C146–39T on the Chemical Analysis of Glass Sand remains unchanged.

Chemical Properties

D. E. Sharp completed his term of office by presenting a voluminous tract on the chemical durability of glass, which represented the work of the subcommittee with his conclusions and recommendations.

The glass-surface accelerated tests have come strongly to the fore, leaving the "glass-as-glass" tests entirely in the academic field.

Among the surface tests, the opinion is growing that more consistent results can be obtained with dilute acid and distilled water as digestive agents than with dilute alkali. (Atlantic City was agreeably surprised to find Mr. Lester advocating water as a digestive medium—for glass containers.)

The importance of rinsing containers before making accelerated surface tests is being stressed. The relation between service tests and accelerated tests is being held constantly in view as a criterion of the desirability of an accelerated test.

Physical and Mechanical Properties

The Committee as a whole voted to amplify the methods of sampling containers for three tentative methods, namely (1) Hydrostatic Pressure Test on Glass Containers (C147–40T); (2) Polariscopic Examination of Glass Containers (C148–40T); and (3) Thermal Shock Test on Glass Containers (C149–40T).

Committee E-10 on Standards has accepted these changes, which specify sampling methods of containers not only in the glass factory, but also in storage, in conveyances, and in stocks both as unused containers and as filled or used containers.

The Committee as a whole voted favorably on a new tentative method, popularly known as the Tentative Method of Measuring the Modulus of Rupture of Glass Test Pieces. To conform with A.S.T.M. practice, the title will be Tentative Method of Flexure Testing of Glass (C158–40T). This method has been accepted by Committee E-10 on Standards and will appear soon in its edited form.

Glass Construction Block and Tile

Manufacturers are working independently and together along similar experimental lines, such as on mortars for use between glass block. This work, delegated to Committee C-12 by C-14, will soon result in tentative specifications. Cooperative work is being continued on physical testing of glass block as well as on the light transmission of panels of glass block. It has been suggested that the subcommittee consider such properties as the heat transfer through glass block, as well as the transmission of solar heat. (This report was submitted for publication on September 4, 1940.)

—Louis Navias, *Secretary*

NORTHERN CALIFORNIA SECTION INTERPLANT SAFETY CONTEST

The following tabulation of injury experience of participants to June 30, 1940, was compiled from data furnished me by the contestants covering (*a*) number of employees in each plant, (*b*) employee hours of work, (*c*) accidental injuries sustained by employees who received medical attention, (*d*) period during which each injured employee was disabled; (*e*) minor injuries which developed infection owing to delayed first aid or medical attention, (*f*) fractures, and (*g*) nature and extent of each permanently disabling injury.

Co. code	No. of employees	No. of employee hr.	Injuries		Lost time injury frequency	Merit		
			No lost time	Lost time		Demerits	Credits	Net
A	60	9385	1	1	106	1.5	0	−1.5
B	12	1733	0	0	0	0	0.5	0.5
D	53	6360 est.	1	1	157	3.5	0	−3.5
E	69	11158	1	0	0	0	0.5	0.5
F	128	20140	0	1	50	0.5	0	−0.5
G	23	4164	0	0	0	0	0.5	0.5
H	42	5946	2	1	168	2.5	0	−2.5
I	209	33832	2	3	89	8.0	0	−8.0
—	—	—	—	—	—	—	—	—
	596	92718	7	7	75	16.0	1.5	−14.5

Note: The 1939 Injury Frequency Rate for the clay products industry was 15.12.

The general rules governing the contest during the period from June 1, 1940, through October 31, 1940, mimeographed copies of which were distributed at the meeting of the Local Section in San Francisco on May 27, 1940, contain no provisions for rating contestants on their Injury Frequency. As the data furnished permits the calculation of Lost Time Injury Frequency (No. of Lost Time Injuries × 1,000,000 ÷ No. of Employee Hours of Work), I have included a Frequency Factor Column in the tabulation so that all of the contestants will have parity insofar as their ratios of disabling injuries to employee hours of work are concerned.

I again urge each company in your Section to enter this contest, regardless of how good or bad your injury experience has been. A Safety Contest is an excellent medium for the promotion of safety education of workers and employers. The natural desire to win stimulates the interest of the workers in the various plants in safe practice, proper maintenance, and good housekeeping, three of the most important essential factors in accident prevention.

Keep these facts constantly in mind: (1) The only way by which accidental injuries can be prevented is to anticipate and prevent accidents which may result in injury. (2) Industrial injuries do not "just happen." They are results of unsafe working practices and unsafe working conditions.

There are two possible causes for industrial accidents under which, broadly speaking, industrial diseases are included: (1) unsafe acts by workers and (2) unsafe working equipment or environment.

For effective accident prevention, adequate information must precede intelligent action.

I recommend that you investigate every accidental occurrence in your plant or elsewhere which endangers your employees, regardless of whether anyone is injured, and that you determine and record in each instance (1) what occurred, when and where it occurred; (2) what persons were involved in the accident; (3) who (if anyone) was injured, nature and extent of the injury, and how the injury was treated; (4) what physical agency and what part of that agency contributed in causing the accident; (5) what action of a person or failure of a person to act contributed in causing the accident; (6) what the employer or his supervisor could have done to prevent the accident; (7) what the persons involved could have done to prevent the accident; (8) what corrective action was recommended or taken by the supervisor of the department in which the accident occurred to prevent the recurrence of a similar accident; and (9) what action the employer took to correct the unsafe act or unsafe conditions which caused the accident, and when such action was taken.

—C. L. Barr, *Superintendent, Safety Engineering, State Compensation Insurance Fund*

FIFTH ANNUAL PORCELAIN ENAMEL INSTITUTE FORUM PROGRAM

The Fifth Annual Porcelain Enamel Institute Forum will be held at the University of Illinois, Urbana, Ill., on October 16, 17, and 18.

Wednesday, October 16

MORNING

COMMITTEE MEETINGS AND REGISTRATION

AFTERNOON

Chairman: A. I. ANDREWS, Univ. of Illinois

(1) Address of Welcome by M. L. ENGER, Dean, Univ. of Illinois.

(2) Response by P. B. MCBRIDE, President, Porcelain Enamel Institute.

(3) Symposium on Clays by F. J. ZVANUT, Ferro Enamel Corp.; G. H. SPENCER-STRONG, Porcelain Enamel & Mfg. Co.; E. E. MARBAKER, O. Hommel Co.; C. G. HARMAN, Univ. of Illinois; L. A. LANGE, United Clay Mines, Inc.; and R. L. FELLOWS, Chicago Vitreous Enamel Product Co.

EVENING

MOTION PICTURES IN COLOR

(1) "Steel" by the Carnegie-Illinois Steel Co.

(2) "Work at the National Bureau of Standards" by W. N. HARRISON, National Bureau of Standards.

(3) "Bureau Cooperation with the Institute" by the National Bureau of Standards.

Thursday, October 17

MORNING

Chairman: L. C. ATHY, Porcelain Enamel & Mfg. Co.

(1) "Sodium Cyanide Neutralizing" by GLEN GROGAN, R. & H. Chemicals Div., E. I. du Pont de Nemours Co., with comments by C. A. ANDREWS, McCray Refrigerator Co.

(2) "Treated Water in Enameling Industry" by E. H. SHANDS, George D. Roper Corp., and W. S. MORRISON, Illinois Water Treatment Co.

(3) "Infrared Drying (Theory and Practice)" by COMMONWEALTH EDISON CO., with comments by N. H. STOLTE, Enamel Products Co.

(4) "Proper Design of Enamel Driers and Control of Humidity Within Same" by E. W. DANY, Ferro Enamel Corp., with comments by D. J. CHERRY, Kelvinator Corp.

(5) "New Developments in Enameling" by C. S. PEARCE, Porcelain Enamel Institute.

AFTERNOON

Chairman: A. L. MATTHES, Youngstown Sheet & Tube Co.

(1) "Evolution of Enameling Iron" by J. M. VOLZER, Republic Steel Corp.

(2) "Test for Sagging of Iron and Steel Sheets" by F. R. PORTER, Inland Steel Co.

(3) "Stretch Testing" by J. E. SAMS, American Rolling Mill Co., with comments by J. J. CANFIELD, American Rolling Mill Co.

(4) "Iron Oxide in Porcelain Enamel" by PAUL STUFFT, Porcelain Enamel & Mfg. Co.

Student Tour of Laboratories.

EVENING

ANNUAL FORUM BANQUET

Friday, October 18

MORNING

Chairman: C. P. SCRIPTURE, Ingram-Richardson Mfg. Co. of Indiana

(1) "Use of Nepheline Syenite in Enameling" by H. L. COOK, Norge Corp.; C. J. KOENIG, Engineering Expt. Station, Ohio State Univ.; and F. A. PETERSEN, Ingram-Richardson Mfg. Co. of Indiana.

(2) "Cover-Coat Practice for Quality Work" by G. N. TUTTLE, Porcelain Enamel & Mfg. Co.

(3) "Results of Fine Grinding of Colors" by N. H. STOLTE, Davidson Enamel Co.

(4) "Control Performance and Cost in Enamel Plant" by E. W. DIETTERLE, American Stove Co.

AFTERNOON

Chairman: F. E. HODEK, JR., General Porcelain Enameling & Mfg. Co.

(1) "Development of Two Tentative Standard Tests" by P. L. SMITH, Research Fellow, Porcelain Enamel Institute.

(2) Questions and Answers by F. E. HODEK, JR., and a special "Board of Experts."

CANADIAN CERAMIC SOCIETY

The Thirty-Eighth Annual Convention of the Canadian Ceramic Society will be held at the Chateau Laurier, Ottawa, Canada, Friday and Saturday, October 18 and 19, 1940.

Among those who will present papers are Frank E. Lathe, Director of Information, National Research Laboratories; W. Butler, Ferro Enamels (Canada), Ltd.; and George Kirkendale, Industrial Mineral Division. Plant visits have been arranged and special social activities have been planned for the ladies.

The officers of the Canadian Ceramic Society are H. A. Bevens, *President*, Insulation Products, Ltd., Toronto, and Gordon C. Keith, *Secretary*, 49 Turner Rd., Toronto.

The Ottawa Committee in charge of arrangements for the Convention is composed of Howells Fréchette, *Chairman;* Duncan C. Merkley, E. A. McDonald, Henry D. McLaren, Frank E. Lathe, J. Gordon Phillips, William Findlay, P. H. Swalm, Donald Beach, and Frank Tilson.

OHIO CERAMIC INDUSTRIES ASSOCIATION

The Ohio Ceramic Industries Association will hold its annual meeting at the Ohio State University, Columbus, Ohio, Friday and Saturday, November 1 and 2.

On Friday morning, there will be a general meeting for all Divisions, with two speakers.

Symposia on the methods and uses of tests for raw materials, plant control, and finished products will be held on Friday afternoon by the Refractories, Structural Clay Products, and Whiteware Divisions, respectively.

On Saturday morning, demonstrations will be given of various tests and testing equipment in the Engineering Experiment Station. These will include a number of tests which have been developed in the Experiment Station but are not yet in general use.

The Association will attend the Ohio State-Indiana football game on Saturday afternoon.

ILLINOIS CLAY MANUFACTURERS' ASSOCIATION

The annual fall meeting of the Illinois Clay Manufacturers' Association was held September 27 and 28. The program consisted of plant trips to the Standard Brick & Tile Corp., Evansville, Ind., and the Albion Brick Co., Albion, Ill.

DAVID ASCH DIES IN POLAND

David Asch, who with his brother, Wladislaus Asch, was co-author of Silicates in Chemistry and Commerce, which appeared in 1914, died in Warsaw, Poland, in March, 1940.

Dr. Asch was born in Plotzk (Russian Poland) in 1876. After completing his high-school training in his native town, he went to Berlin, Germany, to continue his studies, because the discrimination against Jews in Russia was such as to prevent his acquiring a university education there. He joined his older brother, Wladislaus, who was already in the chemistry department of the University of Berlin, and obtained his Doctor of Philosophy degree *cum laude*. He was interested in silicate research, a phase of which served as the topic for the doctorate thesis.

After obtaining the degree, he remained in the University and conducted further silicate researches. The volume on

Silicates in Chemistry and Commerce was based on a new theory of the structure of silicates, namely, the "hexite-pentite theory," which the brothers originated. The contribution was considered so important that the authors were given an award from the Beneke bequest of the University of Göttingen. The volume was published in Germany and was almost immediately translated and published in England. The establishing of important relationships between silicon and carbon stimulated organic research, for much of which Dr. Asch was indirectly responsible.

David Asch

Although he was constantly engaged in research, Dr. Asch published few journal articles. With his brother, he contributed one on "Chemical Constitution of the Kaolinite Molecule"; another on "Topical Parameters in the Light of the Stereo-Hexite-Pentite Theory"; and a third on "The Constitution of Zinnwaldite and Cryophyllite in the Light of the Stereo-Hexite-Pentite Theory." These appeared prior to 1916 in the *Zeitschrift für Krystallographie und Mineralogie.*

David Asch and his brother operated a factory in Berlin, known as Gebrueder DDr. Asch Chemische Fabrick, where, in addition to special chemicals, they were engaged largely in the production of dental porcelain. David Asch was probably the greatest authority on dental porcelain in Europe.

At the time of his death, he had almost completed the manuscript for another book on which he had worked for over twenty years. Thus far no trace of the copy has been found.

Dr. Asch, who was unmarried, is survived by a brother, Joseph Asch, of Brooklyn, N. Y., and two other brothers, Michael and Leo, now residing in that portion of Poland which is under Russian control.

OBJECTIVES AND PLANS FOR ART WEEK, NOVEMBER 25 TO DECEMBER 1

American Art Program Activities

Our country is turning today toward the arts as at no other time in the history of the Republic. A great tide of popular interest in American art has been rising during the past few years. There are strong currents toward an art of native character and native meaning which shall express, with clarity and power, the interests, the ideals, and the experience of the American people. It is a significant fact that our people in these times of world emergency are turning more and more to their own cultural resources.

American art, during the past decade, has been democratized, popularized, and made familiar to the average American in the same way that American sports, American skyscraper architecture, and American literature are familiar to him. Popular magazines, reaching millions of persons every week, feature reproductions of works of art in color. In 1939, 250 books devoted to the arts were published and many of these made their way into the "best-seller" class. Radio series dealing with art appreciation are becoming a standard feature of American broadcasting.

Popular participation in art activity is enormous. Art museum attendance runs into twenty millions a year. Nearly two million persons saw the art exhibitions at the two World's Fairs last year. The attendance this year at the American art exhibition at the New York World's Fair has been extraordinary, running as high as 24,000 in a single day. A week of open house held in May, 1940, by the sponsors of WPA professional and service projects brought a total of 380,612 visitors to art and craft projects. The average monthly attendance at the 82 community art centers of the WPA Art Program is 305,000, an annual total of 3,660,000. The 500,000 weekly average of persons participating in arts and crafts activities in the WPA Playground and Recreation Program, the 15,000 young people enrolled in various types of arts and crafts activities in NYA, and the thousands of members of Home Demonstration and 4-H Clubs under the Extension Service of the United States Department of Agriculture taking advantage of art educational opportunities are indications of the many millions of persons participating in the arts in all regions of this country—in schools, colleges, museums, libraries, churches, clubs, and other social groups.

Under the government art programs, 995 murals and 231 sculptures have been undertaken in post offices and other Federal buildings in 1019 cities by the Section of Fine Arts; 1550 murals and 4200 sculptures for municipal buildings in every part of the country; 52,000 paintings and 95,000 fine prints; and many thousands of crafts objects have been allocated to public institutions by the WPA Art Program.

Market Possibilities for Amerian Art

These figures indicate that in the past few years the American art audience has grown to include nearly a third of our population. Very few of our artists, craftsmen, and designers, however, are able to support themselves by the sale of their work, and very few dealers in art are able to show a profit at the end of the year. In spite of the fact that the interest in American art is greater than ever before, the American artists, craftsmen, and designers are still engaged in a marginal occupation. A broad foundation for a potential public art market has been laid during the past few years. But so far no coordinated effort has been made on a national scale to put into motion the forces that will bring the work of our artists and craftsmen directly to the American home, the church, the business office, and the club, thus opening up broad potentialities of the American art market.

Patronage, both public and private, is necessary if American art is to continue its present remarkable development. Art forms continue in a healthy state only as long as society supplies them with the necessary circulation. The arts, if they are to develop freely, must

move through the main arteries of our contemporary life.

We are in a period of transition as far as art patronage is concerned. We are turning from a system of art patronage supported by a few art collectors to one which has the possibility of enlisting the active support of the whole American people—the thirty million American homes which are potential consumers of American art. Such a program cannot be consummated overnight, nor even in a period of years. It is a long-term process, but a beginning can be made. The present opportunity for making a coordinated effort to bring works of American art into every American home should not be allowed to pass.

Nation-Wide Art Fair

In a belief that American art is one of the daily needs of the American people and that works of art may be sold at prices which the average American home can afford, an organization has been set up to carry out a program which, during the week of November 25 to December 1, 1940, will bring American art to the attention of every potential art consumer in America.

A slogan has been adopted, "American Art for EVERY American Home."

Date

Art Week will be celebrated throughout the United States November 25 to December 1, 1940.

Purpose

A coordinated effort will be made on a national scale to put into motion community forces that will bring the work of American artists and craftsmen into the American home, the business office, the church, the club, and the social group.

Method

A nation-wide program of local sales exhibitions and demonstrations will be organized and conducted with the cooperation of all individuals, groups, organizations, and agencies, public and private, interested in the arts.

Duration

All exhibitions and sales displays will open simultaneously on Monday, November 25, at an appointed hour. The period of national promotion will continue for one week, and local sales exhibitions will run for usual exhibition periods lasting from two to six weeks.

Policy

Exhibitions and sales will be the responsibility of the community committees. Existing resources and facilities of the art programs carried on in the several Government agencies will serve to coordinate the various elements of the program.

It should be clear that the sales exhibitions are to be conducted not for profit or for the benefit of charitable enterprises but solely for the purpose of providing sales outlets for American art through bringing it to the attention of the American consumer.

All artists, designers, and craftsmen living and working in America are eligible to submit work for sale. (*This excludes all work which is produced under government art programs and is public property.*)

Dealers and other representatives of artists, designers, and craftsmen may submit work. Work in all recognized media in the field of the fine arts and crafts may be included.

Sales exhibitions will be selected and approved by exhibition committees to be appointed by local Art Week committees in line with policies of the National Council for Art Week.

Exhibitions

Emphasis on the program will center on the local sales exhibitions in all parts of the country. The character and location of these sales exhibitions will vary according to the local situation. They may be held in established galleries, museums, schools, libraries, department stores, community centers, dealer galleries, appropriate outdoor places, or in locations readily accessible to the largest number of people and offering the best sales possibilities.

Prices

Exhibitors should be encouraged to price their work as moderately as possible and to submit work that can be priced within the means of the average consumer in order to reach groups not heretofore included in the art-purchasing public.

Organization

The basic organization will consist of the National Council for Art Week with a chairman, state committees, and local committees. Specific suggestions for carrying on each phase of the program will be made available by the National Council for Art Week.

National Promotion

Under the leadership of the National Council for Art Week, a nation-wide program of promotion will be inaugurated. Suggestions will be made also to state and local committees on plans and methods for general promotion through local channels.

NEW CALCITE SOURCE DISCOVERED

A new source of calcite, or Iceland spar, a valuable optical mineral heretofore imported from abroad, has been reported by officials of the Bausch & Lomb Optical Company, who have contracted for the output of a new mine in the San Pedro mountains, northwest of Santa Fe, N. Mex.

The scarcity of optical calcite has caused a world-wide search for many years, inasmuch as the mineral is essential in the construction of all polarizing instruments. With the flooding of the Iceland mine at Helgustadir during the World War, this source which formerly supplied the world has been unproductive of fine crystals. Meager supplies have come from various countries, the most recent from Spain and South Africa, but the total volume offered for sale has been insignificant for many years.

The new mine has delivered more than five hundred pounds of fine calcite crystals within a period of three months, many of them weighing as high as forty pounds. An analysis of the output of the new mine indicates that the United States now has a supply of calcite of high optical quality which will serve the country for years.

Calcite, or Iceland spar, takes its name from the country in which it was first discovered. No crystals of sufficient purity, transparency, and perfection of crystalline structure were discovered until early in the seventeenth century, when its powers of double refraction were studied by Bartholinus and Christian Huygens.

The mineral is formed by a deposition of calcium carbonate from water solution, but the conditions necessary for the formation of transparent spar, rather than ordinary calcite, are not definitely known.

The most important use of Iceland spar is for the manufacture of Nicol prisms, essential optical parts of polarizing microscopes, saccharimeters, colorimeters, polariscopes, and many other instruments vital to research and technology. This type of prism was designed by William Nicol, a Fellow of the Royal Society of Edinburgh, in 1828.

When a ray of light passes through a rhombohedron of calcite, it is resolved into two rays of plane polarized light, each vibrating in a single plane perpendicular to the other. The two rays have different indices of refraction which results in their following different paths through the crystal.

In the petrographic microscope, the Nicol prism is used to provide a source of polarized light for the accurate study and identification of minerals; it is used in the chemical microscope to identify a great variety of crystals and to study their properties. Saccharimeters require a polarizer to measure the sugar content of a solution; colorimeters utilize a polarizing prism in indicating the depth of color of solutions; polariscopes and photoelastic instruments utilize polarized light to disclose stresses and strains in transparent objects.

THE BALTIMORE MUSEUM OF ART

The Baltimore Museum of Art was incorporated in 1914 to establish and maintain in the city of Baltimore a museum of art to encourage and promote the study and enjoyment of the fine arts. The present Museum building was completed in 1928, and the new wing, housing the collection of Mary Frick Jacobs, was completed in 1938. Collections, chiefly indefinite loans, are shown in twenty galleries. These collections include paintings and sculpture by American and foreign artists; the Mary Frick Jacobs collection of paintings, tapestries, jades, amber, amethyst, crystals, and porcelain; the Jacob Epstein collection of paintings and bronzes; the De Weerth collection of paintings; the White collection of Maryland silver; the Garrett collection of prints, consisting of 28,000 items; the Lucas collection of prints and paintings; the Conrad collection of prints; the Adler and May collections of prints, sculpture, painting, furniture, and textiles; Cypriote antiquities; a Maryland wing containing colonial rooms and Americana; Antioch mosaics; and the Julius Levy Memorial Room containing Oriental art.

Until January, 1938, the Baltimore Museum of Art was similar to other museums in policy and manner of presentation of exhibitions. Upon the resignation of Roland J. McKinney as Director, Henry E. Treide, President of the Board of Trustees of the Museum, undertook to direct the administration of the Museum until a new director could be found. Mr. Treide's policy took the form of questioning the Baltimore public as to the type of exhibitions which the Museum should present. Every organization in Baltimore—religious, educational, business, social, and cultural—was reached for this city-wide poll. The results of the balloting were directly responsible for the exhibitions held in the Museum during 1938–1939, namely, labor in art, religious art, negro art, non-objective paintings from the Guggenheim collection, a patriotic show, a photography salon, a showing of the work of local artists, and an architectural exhibition. When the new director, Leslie Cheek, Jr., took over executive duties in September, 1939, he strengthened contacts with all phases of Baltimore's community life and enterprises. In addition to selecting the subject of various exhibitions with an eye to the interests of the Baltimore public, Mr. Cheek endeavored also to "democratize" the method of presenting each exhibition. First of all, the Museum's galleries, ordinarily lined in conventional fashion with the works of art on display, were broken up by temporary partitions to block off natural divisions in subject matter, either by period, influence, or contingent interests. The divisions were painted in various brilliant colors; indirect lighting was made the most of to display the material to the best advantage and

Baltimore Museum of Art Entrance Court

Baltimore Museum of Art Opened April 18, 1929

with regard to ease of enjoyment on the part of the museum visitor. In addition, these partitions were often utilized to display large captions and running heads—clearly typed labels and descriptions which endeavored to present the brief of each exhibition in such form that even the most untutored art admirer could grasp the background and significance of the current exhibition. These blurbs were worded in lively style—in everyday parlance in lieu of technical terms. Passage through the galleries, furthermore, took the form of a well-planned route—the only choice the visitor had—to insure that the exhibitions would be viewed in the proper sequence.

This method, new when Mr. Cheek first presented it in Baltimore in the fall of 1939, aroused considerable controversy among the diehards in Baltimore's art circles who were accustomed to walls literally lined with masterpieces. Despite comment, however, this manner of installation has been found to be so effective that it has attracted crowds to the Museum's exhibitions which have broken all attendance records.

In scrapping old ideas of "art appreciation," Mr. Cheek has been guided largely by his belief that "art should be fun" for the average visitor. In Mr. Cheek's opinion, the visitor should approach it as a pleasure, as something that is not confined to a blessed circle of aesthetes but is the enjoyable privilege of everyone. The public must believe that art is not something beyond its comprehension and that art *is* a definite means to promote better living, materially and artistically. In presenting the exhibitions in this fashion, Mr. Cheek has made it possible for the most timid visitor to secure enough information on the shows to guarantee his critical appreciation of them, and at the same time the information which is thus made accessible to the unschooled has not been arranged in such a way that it infringes on the enjoyment of the initiated.

The contents of the exhibitions have not been limited to painting and sculpture; the gamut which the Museum ran during the past season extended from Medicean art to twentieth-century industrial design. So varied are the mediums and categories which a civic Museum must consider that any attempt to include even the most representative in a one-year program is impossible. It is, therefore, with considerable anticipation that the Baltimore Museum of Art plans to round out its first year of experimental methods of presentation with a second year that will—where contents are concerned—complement the earlier undertakings.

PACIFIC COAST BORAX COMPANY CELEBRATES FIFTIETH ANNIVERSARY

The Pacific Coast Borax Company will celebrate its golden anniversary through October, marking the completion of a half-century of service in one of America's most colorful industries. The Company will observe simultaneously the tenth anniversary of its radio program, "Death Valley Days," the oldest half-hour dramatic program on the air.

This anniversary will also celebrate the use of the famous Company trademark, the "Twenty-Mule Team."

The Company, which was incorporated in 1890, has been engaged in the discovery, mining, and refining of borax and in the development and manufacture of borax products.

In the span of fifty years, the Company has seen the use of borax steadily increase from drug purposes until today this product of the desert has countless essential uses in the home, in agriculture, and in industry. It would be difficult to name an important industry to whose products borax does not contribute, from leather to pottery, from glassware to metals, and from enamels to textiles. Owing to a constantly greater demand for borax, greater production, and improved mining, refining, and transportation methods, bulk prices of borax for industrial uses have been progressively lowered; borax prices in the latter part of the nineteenth century were 1200% higher than they are today. Total consumption has increased from only a few hundred pounds a year to thousands of tons annually.

Although it was incorporated in 1890, the history of the Pacific Coast Borax Company is said to have begun on a day in 1881 when Aaron Winters, an aging prospector, together with his half-Spanish wife, Rosie, discovered borax in the dry desert marshes on the floor of Death Valley. Winters fired the chemical used to identify borax, then shouted, "She burns green, Rosie! We're rich!" Winters sold his claim to W. T. Coleman of San Francisco, who established the Harmony Borax Works near the mouth of Furnace Creek. It was to carry the precious borax ore from Death Valley across more than 160 miles of blistering desert to the railroad at Mojave that the great twenty-mule team trains were developed. Probably the largest wagons ever built, two of them together were capable of transporting twenty-four tons of borax, equal to a railroad carload.

New deposits of borate of lime called "colemanite" were later discovered in ore form which was purer and also more easily worked than surface deposits, and the Company moved its operations to Borate, Calif., which was near the Sante Fe Railroad in the Calico Mountains southwest of Death Valley. What is believed to have been the first calcining plant in California was established at Borate. Ore was carried over a narrow-gauge railroad from mine to plant in small cars drawn by a sturdy little locomotive named "Francis."

When the borate deposits at this location had been worked out, the Company again moved back into the vicinity of Death Valley, mining borate minerals in the Black and Funeral mountains in and around Ryan, Calif. With the construction of the Tonopah & Tidewater Railroad, which skirts the eastern rim of Death Valley, the first railroad to penetrate this region, a twenty-mile narrow-gauge railway was built from Death Valley Junction to the mines. Known as the Death Valley Railroad, it was considered to be one of the engineering marvels of its day because of the steep grades, the rough character of the country, and the dangers from cloudbursts which had to be overcome.

It was not until 1927 that the Pacific Coast Borax Company moved to its present location at Boron, near Kramer, Calif., which was nearer the seaboard and where a large deposit of borate of soda, known as "rasorite," had been discovered by C. M. Rasor, the Company's field engineer. From the calcining plant at Boron, borax ore now is transported to one of the country's largest borax refineries at Wilmington, Calif., where it is refined, manufactured into Twenty-Mule Team products, and shipped throughout the world.

(1940)

Membership in
The American Ceramic Society
FOR CONTINUING EDUCATION
IN CERAMICS

NORTH AMERICAN REFRACTORIES COMPANY ELECTIONS

The Board of Directors of the North American Refractories Company, Cleveland, Ohio, has made several changes and promotions in the organization.

Ralph F. Hess, production manager since the formation of the Company in 1929, has been elected vice-president in charge of operations. Howard H. Hopwood, sales manager since 1936, has been elected vice-president and general sales manager.

Stephen M. Swain, chief ceramic engineer since 1934, has been appointed director of research. Mr. Swain became a member of The Society in 1926 and was elected to the Fellowship in 1937.

Earl C. Petrie, who has been doing research work under Stuart M. Phelps on the American Refractories Fellowship at the Mellon Institute, Pittsburgh, Pa., for the past eleven years, has been employed in the Research Department since September 1. He was graduated in ceramic engineering from Ohio State University.

Mr. Hess and Mr. Petrie are members of The American Ceramic Society.

Earl C. Petrie

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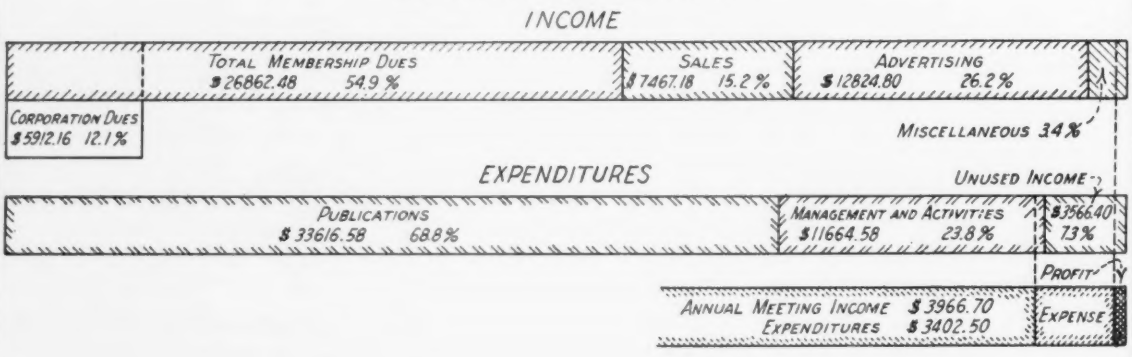

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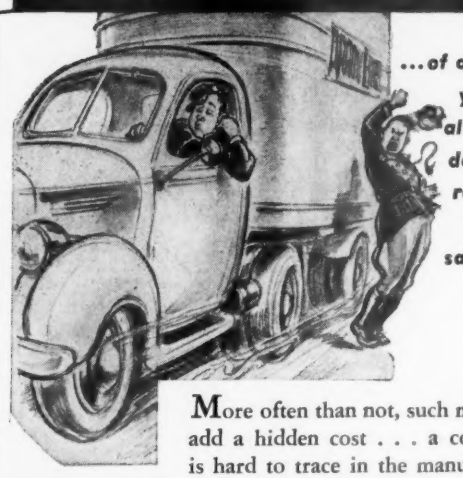

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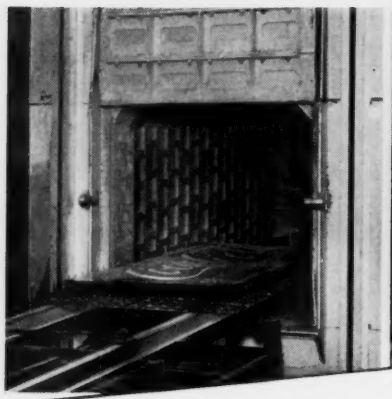

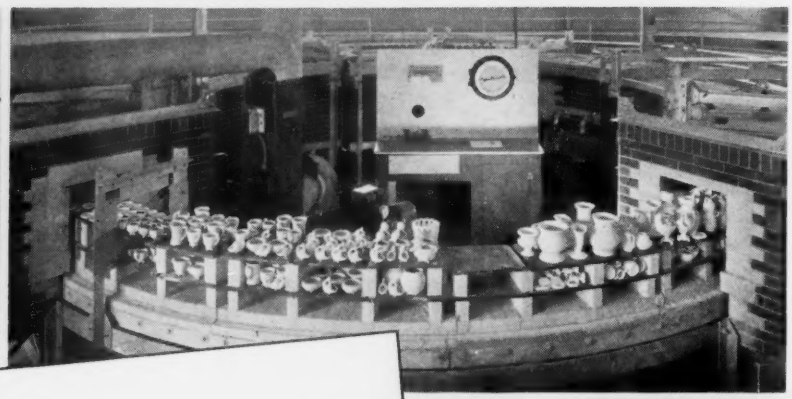

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Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
The Vitro Mfg. Co.

Alumina (Fused) Brick and Tile
The Vitro Mfg. Co.

Aluminum Oxide (Calcine)
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Aluminum Oxide (Fused)
Carborundum Co.
Harshaw Chemical Co.
Norton Co.
The Vitro Mfg. Co.

Alundum (Refractory Products)
Norton Co.

Ammonium Bicarbonate
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Solvay Sales Corp.

Ammonium Bifluoride
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc. R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Ammonium Carbonate
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Antimony Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Antimony Sulphide
Edgar Plastic Kaolin Co.
Foote Mineral Co.
The Hommel, O., Co., Inc.

Arches (Interlocking, Suspending, and Circular)
Frazier-Simplex, Inc.
Green, A. P., Fire Brick Co.

Arsenic
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.

Automatic Brick Car Loaders
Lancaster Iron Works, Inc.

Ball Mills
Ceramic Color & Chemical Mfg. Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
McDanel Refractory Porcelain Co.
The Vitro Mfg. Co.

Ball Mills (Laboratory Type)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
The Vitro Mfg. Co.

Barium Carbonate
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Foote Mineral Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Basic Oxides
Porcelain Enamel and Mfg. Co.

Batch Systems
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.
National Engineering Co.

Batts
Carborundum Co. (*"Carbofrax Aloxite"*)
Denver Fire Clay Co.
Norton Co. (*Alundum-Crystolon*)

Beryl
Foote Mineral Co.

Bichromate of Soda
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Bitstone
Potters Supply Co.

Blocks (Refractory)
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Green, A. P., Fire Brick Co.
Louthan Mfg. Co.
Norton Co.
The Vitro Mfg. Co.

Body Stains
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.

Bone Ash
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Borax
American Potash & Chemical Corp.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pacific Coast Borax Co.
The Vitro Mfg. Co.

Borax Glass
American Potash & Chemical Corp.
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pacific Coast Borax Co.
The Vitro Mfg. Co.

Boric Acid (Anhydrous)
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pacific Coast Borax Co.
The Vitro Mfg. Co.

Boric Acid (Crystal, Granular, or Powder)
American Potash & Chemical Corp.
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pacific Coast Borax Co.
The Vitro Mfg. Co.

Boron Carbide
Norton Co.

Brick Machines (also Barrows, Molds)
Lancaster Iron Works, Inc.

Brick (Refractory)
Carborundum Co. (*"Carbofrax Aloxite"*)
Corhart Refractories Co.
Denver Fire Clay Co.
Green, A. P., Fire Brick Co.
Norton Co.
The Vitro Mfg. Co.

Cadmium Sulphide
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Carbofrax (Refractory Products)
Carborundum Co.

Carbonates (Barium, Lead)
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Castings
Lancaster Iron Works, Inc.

Castings (Abrasive Resisting)
Bethlehem Steel Co.

Caustic Potash
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Solvay Sales Corp.

Caustic Soda
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
Solvay Sales Corp.
The Vitro Mfg. Co.

Cements
Carborundum Co.
Corhart Refractories Co.
Green, A. P., Fire Brick Co.
Norton Co.
Pennsylvania Salt Mfg. Co.

Ceramic Chemicals
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Pennsylvania Salt Mfg. Co.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Cerium Oxide
Drakenfeld, B. F., & Co.
Foote Mineral Co.

Chromite (Natural Chromate of Iron)
Foote Mineral Co.

Chromium Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Clay (Ball)
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Paper Makers Importing Co.
Potters Supply Co.
Spinks, H. C., Clay Co.
United Clay Mines Corp.
The Vitro Mfg. Co.

Clay (Bentonite)
Edgar Plastic Kaolin Co.
Great Lakes Foundry Sand Co.

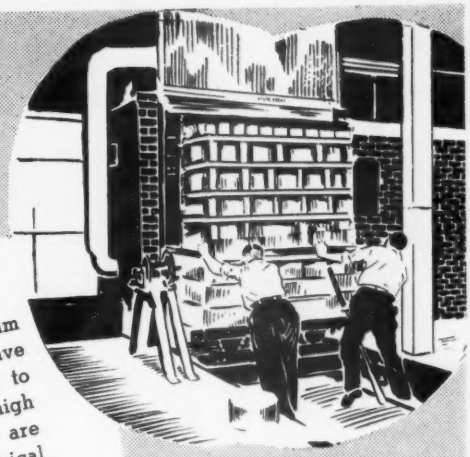
Clay (Block)
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.

Clay (China)
Ceramic Color & Chemical Mfg. Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.
The Vitro Mfg. Co.

Clay—Cleaners, Feeders
Lancaster Iron Works, Inc.

Clay (Electrical, Porcelain)
Ceramic Color & Chemical Mfg. Co.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
The Hommel, O., Co., Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Paper Makers Importing Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.

HANDLING HEAT
for the Ceramic Industry



Kiln Linings—

In both tunnel and periodic kilns Alundum Corrugated Plates, Tiles and Brick have demonstrated conclusively their ability to stand up for years under constant high temperatures. In countless plants they are cutting lining costs because of their chemical stability, high refractoriness, high heat conductivity and high strength.

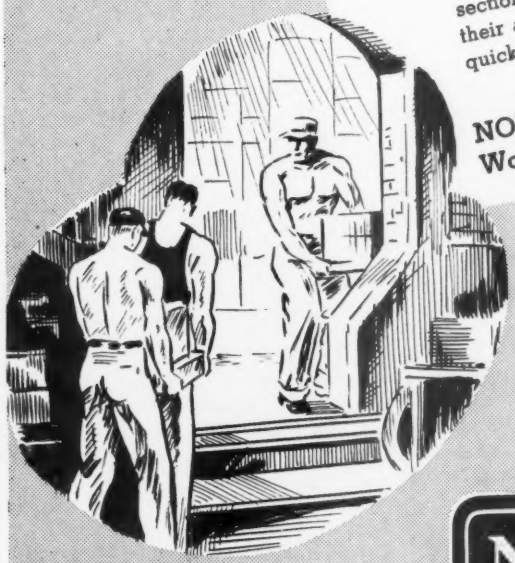
Kiln Furniture—

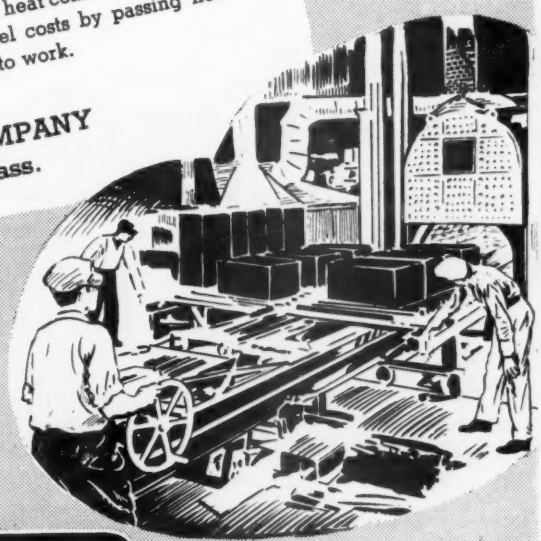
Because it increases kiln capacity and has long life, Crystolon Kiln Furniture (Batts, Saggers, Supports, Car Tops) is saving money for many users. Made of Norton silicon carbide it is strong and can be safely used in very thin cross-section, thus giving more usable kiln space. It is long lived because it resists temperature and mechanical shocks and is very resistant to warpage.

Enameling Muffles—

From the high refractoriness and chemical stability of Alundum Muffles and Brick for enameling furnaces comes their ability to give long, trouble-free service. From their high strength which allows plates of thin cross-section and their high heat conductivity comes their ability to cut fuel costs by passing heat quickly from source to work.

NORTON COMPANY
Worcester, Mass.





NORTON
REFRACTORIES

R-661

Clay (Enamel)
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Metal & Thermit Corp.
Paper Makers Importing Co.
Porcelain Enamel and Mfg. Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.
Titanium Alloy & Mfg. Co.
United Clay Mines Corp.
The Vitro Mfg. Co.

Clay (Fire)
Denver Fire Clay Co.
Great Lakes Foundry Sand Co.
Maxson, Elwyn L.
Paper Makers Importing Co.
Potters Supply Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.

Clay (German Vallendar)
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Kentucky Clay Mining Co.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Clay (Micronized)
Porcelain Enamel and Mfg. Co.

Clay Miners
Edgar Plastic Kaolin Co.
Great Lakes Foundry Sand Co.
Maxson, Elwyn L.
Paper Makers Importing Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.

Clay (Potters)
Denver Fire Clay Co.
Hammill & Gillespie, Inc.
The Hommel, O., Co., Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Paper Makers Importing Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.

Clay (Process Equipment)
Lancaster Iron Works, Inc.
National Engineering Co.

Clay (Sagger)
Edgar Plastic Kaolin Co.
Great Lakes Foundry Sand Co.
The Hommel, O., Co., Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Paper Makers Importing Co.
Potters Supply Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.

Clay-Slip (Albany)
Hammill & Gillespie, Inc.
United Clay Mines Corp.

Clay (Wad)
Kentucky Clay Mining Co.
Potters Supply Co.
Spinks, H. C., Clay Co.
Thomas Albama Kaolin Co.
United Clay Mines Corp.

Clay (Wall Tile)
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Kentucky Clay Mining Co.
Maxson, Elwyn L.
Paper Makers Importing Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.

Cleaners
Pennsylvania Salt Mfg. Co.
Porcelain Enamel and Mfg. Co.

Cleaners, Chemical
Harshaw Chemical Co.
Pennsylvania Salt Mfg. Co.

Clocks (Gauge Board)
The Hommel, O., Co., Inc.

Cobalt Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Cobalt Sulphate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Colors
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Cone Plaques
Industrial Ceramic Products, Inc.

Cones
Accurate Pyrometric Cone Co.
The Edward Orton, Jr., Ceramic Foundation

Conveying Equipment
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.
National Engineering Co.

Copper Oxide
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Corhart
Corhart Refractories Co.

Cornwall Stone (Imported)
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.

Crucibles (Filter, Melting, Ignition)
Carborundum Co.
Denver Fire Clay Co.
Norton Co.
Potters Supply Co.

Crushers (Clay)
Lancaster Iron Works, Inc.

Cryolite (see Kryolith)
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
The Vitro Mfg. Co.

Crystolon (Refractory Products)
Norton Co.

Cullet, Washing Plants, Incinerators, Crushers
Frazier-Simplex, Inc.

Cutters (Bar)
Industrial Ceramic Products, Inc.

Decorating Supplies
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Disintegrators
Lancaster Iron Works, Inc.
National Engineering Co.

Dryer (Pipe Rack)
Lancaster Iron Works, Inc.

Drying Machinery
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.
Proctor & Schwartz, Inc.

Electrocast Refractories
Corhart Refractories Co.

Enamelers' Borax
Porcelain Enamel and Mfg. Co.

Enameling Equipment (Complete)
Ceramic Color & Chemical Mfg. Co.
Frazier-Simplex, Inc.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
The Vitro Mfg. Co.

Enameling Furnaces
Carborundum Co.
Ceramic Color & Chemical Mfg. Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Lancaster Iron Works, Inc.
Norton Co.

Enameling Iron (Sheet)
American Rolling Mill Co.
Bethlehem Steel Co.

Enameling Muffles
Bethlehem Steel Co.
Carborundum Co. (*Carbofrax*)
Frazier-Simplex, Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Norton Co. (*Alundum*)

Enameling (Practical Service)
Ceramic Color & Chemical Mfg. Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Metal & Thermit Corp.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Enamels
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Enamel Oxide
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.

Enamels (Porcelain)
Ceramic Color & Chemical Mfg. Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Equipment (Porcelain Enameling)
Ceramic Color & Chemical Mfg. Co.
The DeVilbiss Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.

Exhaust Systems
The DeVilbiss Co.

Feldspar
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Filter Fabrics
Metakloth Company

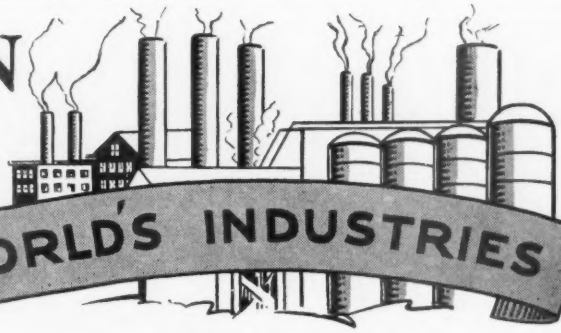
Fire Brick
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Green, A. P., Fire Brick Co.
Norton Co.

Fire Brick—Process Equipment
Lancaster Iron Works, Inc.

Fire Clay
Denver Fire Clay Co.
Great Lakes Foundry Sand Co.
Green, A. P., Fire Brick Co.
Spinks, H. C., Clay Co.
Thomas Alabama Kaolin Co.

Flint
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Great Lakes Foundry Sand Co.
Harshaw Chemical Co.

A. P. GREEN
REFRACTORY PRODUCTS



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INSULATING FIRE BRICK
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CASTABLES

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THE MOST ADVANCED FIRE BRICK PLANT IN THE WORLD
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CLAYS
English China and Ball

TALCS
for

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SAGGER USES

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Cornwall Stone : Barium Carbonate
Zinc Oxide : Enameling Clays : Etc.

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"Ceramic" Colors AND Chemicals

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for POTTERY
· GLASS
· ENAMEL

See our catalog in Ceramic Data Book

CERAMIC COLOR AND CHEMICAL MFG. CO.
New Brighton, Pa., U. S. A.

The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Porcelain Enamel and Mfg. Co.

Flint Pebbles
Ceramic Color & Chemical Mfg. Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
The Vitro Mfg. Co.

Floors (Non-Slip)
Norton Co.

Fluorspar
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

French Flint
Maxson, Elwyn L.
Paper Makers Importing Co.

Frit
Ceramic Color & Chemical Mfg. Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Frosting Mixtures
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Fuel Oil Systems and Control, Stokers
Bethlehem Steel Co.
Frazier-Simplex, Inc.

Furnaces
Carborundum Co. (*Carboradiant*)
Denver Fire Clay Co.
Frazier-Simplex, Inc.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Swindell-Dressler Corp.

Furnaces, Enameling
Swindell-Dressler Corp.

Glass Bending Ovens, Glass Decorating Machines
Frazier-Simplex, Inc.

Glass Equipment
Hartford-Empire Co.
Lancaster Iron Works, Inc.

Glass Melting Tanks and Furnaces
Frazier-Simplex, Inc.

Glass Sand
Great Lakes Foundry Sand Co.

Glass Thickness Gauge
Bausch & Lomb Optical Co.

Glaze and Body Spar
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Glazes and Enamels
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Glaze Spar
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.

Goggles
The Hommel, O., Co., Inc.
Willson Products, Inc.

Gold
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Gold Decorations
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.

Granulators
Lancaster Iron Works, Inc.

Grinding Wheels
Carborundum Co. (*Carborundum and Aloxite*)
Chicago Vitreous Enamel Product Co.
Norton Co. (*Alundum-Crystolon*)

Hearths
Carborundum Co. (*Carbofrax* heat treating)
Corhart Refractories Co.
Green, A. P., Fire Brick Co.
Norton Co. (*Crystolon*)

Hearths (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.
Norton Co.

Hose (Air and Fluid)
The DeVilbiss Co.

Hydrofluoric Acid
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Iron Chromite
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.

Iron (Enameling)
American Rolling Mill Co.
Bethlehem Steel Co.

Iron Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Kaolin
Ceramic Color & Chemical Mfg. Co.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Thomas Alabama Kaolin Co.
United Clay Mines Corp.
The Vitro Mfg. Co.

Kilns, China (Decorating)
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Frazier-Simplex, Inc.
The Hommel, O., Co., Inc.
Swindell-Dressler Corp.

Kilns-(Electric, Circular, Tunnel)
Swindell-Dressler Corp.

Kiln Furniture (Silicon Carbide, Semi-Silicon carbide) (Refractory)
Louthan Mfg. Co.

Kyanite
Celo Mines, Inc.

Kryolith (see Cryolite)
Pennsylvania Salt Mfg. Co.

Laboratory Ware
Norton Co.

Lehr Tile (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.

Lehrs
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehrs (Electric or Fuel Heated)
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehr Loaders
Frazier-Simplex, Inc.

Linings (Furnace Refractory, Block Refractory Plate, Brick, and Tile)
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Norton Co.
The Vitro Mfg. Co.

Lithium Carbonate
Drakenfeld, B. F., & Co.
Edgar Plastic Kaolin Co.
Foote Mineral Co.

Lithium Minerals
Foote Mineral Co.

Loaders (Bucket)
National Engineering Co.

Magnesia (Fused)
Norton Co.

Magnesia (Sintered, Calcined)
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.

Magnesite
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc. R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Magnesite Calcined
Foote Mineral Co.
The Hommel, O., Co., Inc.

Magnesium Carbonate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Manganese
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Manganese Dioxide
Drakenfeld, B. F., & Co.
Edgar Plastic Kaolin Co.
Foote Mineral Co.

Manganese (Oxide)
Ceramic Color & Chemical Mfg. Co.
Cornart Refractories Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Masks (Breathing)
The DeVilbiss Co.
Drakenfeld, B. F., & Co.
Willson Products, Inc.

Metals (Porcelain Enameling)
American Rolling Mill Co.
Bethlehem Steel Co.

Micronized Products
Porcelain Enamel and Mfg. Co.

Microscopes (Polarizing)
Bausch & Lomb Optical Co.
Spencer Lens Co.

Microscopes (Stereoscopic)
Spencer Lens Co.

Minerals
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Mixers
National Engineering Co.

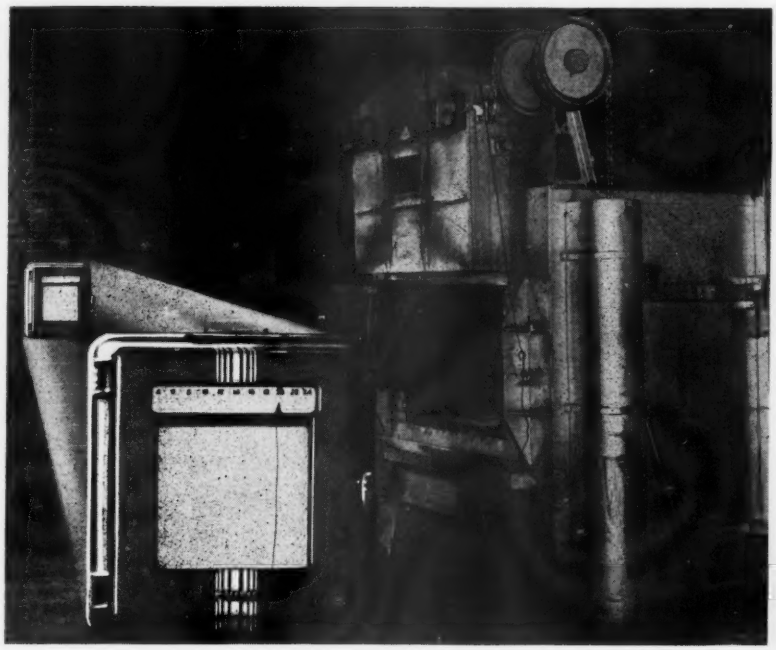
Mixers (Batch)
Lancaster Iron Works, Inc.
National Engineering Co.

Mixers (Concrete, Paving, Road Paving, Plaster, Asphalt, Truck, Mortar, Bituminous)
Lancaster Iron Works, Inc.

Mixers (Laboratory)
Lancaster Iron Works, Inc.
National Engineering Co.

Mold Sanders
Lancaster Iron Works, Inc.

Muffles (Furnace) (Laboratory)
Carborundum Co. (*Carbofrax*)
Denver Fire Clay Co.
Frazier-Simplex, Inc.



Ceramic products are fired, under Micromax Control, in this Lindberg electric furnace.

Overnight Firing Is Dependably Controlled When Furnace Is Micromax-Equipped

Taking charge late every afternoon of a fresh furnace-load of work, the Micromax Pyrometer shown above regulates furnace temperature through the night so dependably that practically every part will, in the morning, meet the requirements of the industry.

Heating is in three stages. Micromax first brings and holds the work to a comparatively low temperature. The next stop is higher and then a long jump, to about 2000 F, brings the parts to firing temperature. This must be within 20 degrees (one per cent), of the theoretically correct point, and the furnace must be uniform throughout to within a very few degrees.

Because this firing is at night, when the control pyrometer has no supervision, the furnace users wanted extreme dependability; and they selected Micromax as the pyrometer. Performance has justified their choice. The pyrometer brings their big furnace to temperature with extreme accuracy, and its broad chart proves the product is fired with quality precision.

But Maybe You Don't Fire Small Articles

Micromax is as dependable in the making of other ceramic materials as in this case. Models meet any plant personnel's preferences; see Catalog N-33A, "Micromax Thermocouple Pyrometers", Catalog N-33B, "Micromax and Speedomax Rayotube Pyrometers" and N-00A, "Micromax Electric Control".

Laboratory Instruments

Jrl Ad EN-0720(3)

Temperature Checking Is Easier With New L&N Direct-Reading Optical

This man, checking temperatures as a glass tank is fired up, finds his job easier, faster and more accurately done because he has a new L&N Optical Pyrometer which reads directly in degrees Fahrenheit.

Gone is the calibration chart used with the earlier Optical. Gone is a third of the weight. And gone, too, is much of the work involved in measuring

Glass plants find New L&N Optical Pyrometer convenient.

temperatures in hard-to-get-at-places, because the new Optical comes more quickly to balance, hence keeps the man on the tank a shorter time. Write for Catalog N-33D, "Optical Pyrometer".

Look To L&N For:

Micromax Controllers, Recorders & Indicators
Speedomax Recorders
Manually-Operated Indicators
Metermax Combustion Control
Centrimax Flowmeter

Instrument and Control Information

Laboratory Instruments

LEEDS & NORTHRUP COMPANY, 4990 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

Measuring Instruments : Telemeters : Automatic Controls : Heat Treating Furnaces

Ingram-Richardson Mfg. Co. of Indiana, Inc.
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National Engineering Co.

Muriatic Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.

Needle Antimony
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Nepheline Syenite
Great Lakes Foundry Sand Co.

Nickel Salts
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Nitrates (Cobalt, Sodium)
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Nitre
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Norbide (Norton Boron Carbide)
Norton Co.

Olivine
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.

Opacifiers
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Metal & Thermit Corp.
Pennsylvania Salt Mfg. Co.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Overglaze Colors
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.

Oxides
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Metal & Thermit Corp.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Palladium Decorations
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.

Pins
The Hommel, O., Co., Inc.
Industrial Ceramic Products, Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Louthan Mfg. Co.
Potters Supply Co.

Pins (Tile Setter)
Louthan Mfg. Co.

Placing Sand
Great Lakes Foundry Sand Co.
United Clay Mines Corp.

Platinum Decorations
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.

Polariscopes
Bausch & Lomb Optical Co.
Frazier-Simplex, Inc.

Porcelain Enameling Service (Practical)
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Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Porcelain Enamels
Ceramic Color & Chemical Mfg. Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Potters Wheels
Denver Fire Clay Co.

Potash (Carbonate)
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc.. R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Solvay Sales Corp.
The Vitro Mfg. Co.

Producer Glass Plants
Frazier-Simplex, Inc.

Pug Mills
Lancaster Iron Works, Inc.

Pyrites (Natural Iron Sulphide)
Foote Mineral Co.
The Hommel, O., Co., Inc.

Pyrometer Tubes
Carborundum Co.
Montgomery Porcelain Products Co.

Pyrometer Tubes (Refractory and Hard Porcelain)
Denver Fire Clay Co.
Green, A. P., Fire Brick Co.
McDanel Refractory Porcelain Co.
Montgomery Porcelain Products Co.
Norton Co.

Pyrometers (Optical, Radiation, Surface, Immersion, Needle)
Leeds & Northrup Co.
Pyrometer Instrument Co.

Pyrometric Cones
Accurate Pyrometric Cone Co.
The Edward Orton, Jr., Ceramic Foundation

Racks, Firing (Refractory)
Louthan Mfg. Co.

Raw Material Handling Equipment
Frazier-Simplex, Inc.
Lancaster Iron Works, Inc.

Refractometers
Bausch & Lomb Optical Co.
Spencer Lens Co.

Refractories
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Green, A. P., Fire Brick Co.
Louthan Mfg. Co.
Norton Co.

Refractory Materials
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Louthan Mfg. Co.
Norton Co.
Titanium Alloy & Mfg. Co.
Thomas Alabama Kaolin Co.

Respirators
The DeVilbiss Co.
Drakenfeld, B. F., & Co.
The Hommel, O., Co., Inc.
Willson Products, Inc.

Rutile
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.
Willson Products, Inc.

Saggers
Carborundum Co.
Norton Co.
Potters Supply Co.

Salt Cake
American Potash & Chemical Corp.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.

Sandblast Helmets
Willson Products, Inc.

Sandblast Sand
Great Lakes Foundry Sand Co.

Sand Grinder and Sifters
Lancaster Iron Works, Inc.

Saponin
The Hommel, O., Co., Inc.

Screening and Magnetic Separators
National Engineering Co.

Selenite of Sodium
Drakenfeld, B. F., & Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Selenium
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Setters (Tableware)
Louthan Mfg. Co.

Sheets (Enameling Iron)
American Rolling Mill Co.
Bethlehem Steel Co.

Silica (Fused)
Edgar Plastic Kaolin Co.
The Hommel, O., Co., Inc.

Silicate of Soda
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Silicon Carbide
Carborundum Co.
Norton Co.

Silicon Carbide Firesand
Carborundum Co.

Sillimanite Refractories
Denver Fire Clay Co.

Slabs (Furnace)
Carborundum Co.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Norton Co.

Soda Ash
American Potash & Chemical Corp.
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
Solvay Sales Corp.
The Vitro Mfg. Co.

Sodium Antimonate
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Sodium Fluoride
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Sodium Metasilicate
Harshaw Chemical Co.

Sodium Nitrite
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Sodium Silica Fluoride
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Sodium Uranate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Soot Blowers
Frazier-Simplex, Inc.

Special Machines
Frazier-Simplex, Inc.

Spar
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Maxson, Elwyn L.
Paper Makers Importing Co.
The Vitro Mfg. Co.

Spray Booths
The DeVilbiss Co.
The Hommel, O., Co., Inc.

Spraying Equipment
The DeVilbiss Co.
The Hommel, O., Co., Inc.

Spurs
Louthan Mfg. Co.
Potters Supply Co.

Stacks
Lancaster Iron Works, Inc.

Steel Plate Construction
Bethlehem Steel Co.
Lancaster Iron Works, Inc.

Stilts
The Hommel, O., Co., Inc.
Industrial Ceramic Products, Inc.
Louthan Mfg. Co.
Potters Supply Co.

Sulfuric Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.

Talc
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Paper Makers Importing Co.

Tanks
Frazier-Simplex, Inc.

Tank Blocks
Corhart Refractories Co.

Tanks (Pickle)
The Hommel, O., Co., Inc.

Tanks for Raw Material Steel or Concrete
Bethlehem Steel Co.
Lancaster Iron Works, Inc.

Tile (Floor)
Norton Co.

Tile (Muffle)
Carborundum Co.
Norton Co.

Tile Setter Pins
Louthan Mfg. Co.

Tile (Refractory)
Carborundum Co. (*Carbofrax*)
Denver Fire Clay Co.
Green, A. P., Fire Brick Co.
Norton Co.
Thomas Alabama Kaolin Co.

Tile (Wall)
Denver Fire Clay Co.
Green, A. P., Fire Brick Co.
Thomas Alabama Kaolin Co.

Tin Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Titanium
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Titanium Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Trisodium Phosphate
Harshaw Chemical Co.

Trucks
Lancaster Iron Works, Inc.

Tubes (Insulating)
Carborundum Co.
Green, A. P., Fire Brick Co.
Louthan Mfg. Co.
McDanel Refractory Porcelain Co.
Norton Co.

Tubes (Pyrometer)
Carborundum Co.
Denver Fire Clay Co.
McDanel Refractory Porcelain Co.
Montgomery Porcelain Products Co.
Norton Co.

Uranium Oxide
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Uranium Oxide (Yellow-Orange-Black)
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Water Softening Plants
Frazier-Simplex, Inc.

Wet Enamel
Ceramic Color & Chemical Mfg. Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Whiting
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Paper Makers Importing Co.
The Vitro Mfg. Co.

Winding Drums
Lancaster Iron Works, Inc.

Zinc Oxide
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Zircon
Edgar Plastic Kaolin Co.
Foote Mineral Co.
The Hommel, O., Co., Inc.

Zirconia
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Metal & Thermit Corp.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Zirconium Oxide
Foote Mineral Co.
The Hommel, O., Co., Inc.
Titanium Alloy Mfg. Co.

Zirkite (Natural ZrO_2)
Foote Mineral Co.

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THE WORLD'S PEMCO FINEST
THE PORCELAIN ENAMEL & MFG. CO.
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Sanitary features alone, besides other ones, needed in every home, institution, etc.

A money maker for a live pottery.

Royalty basis, write,

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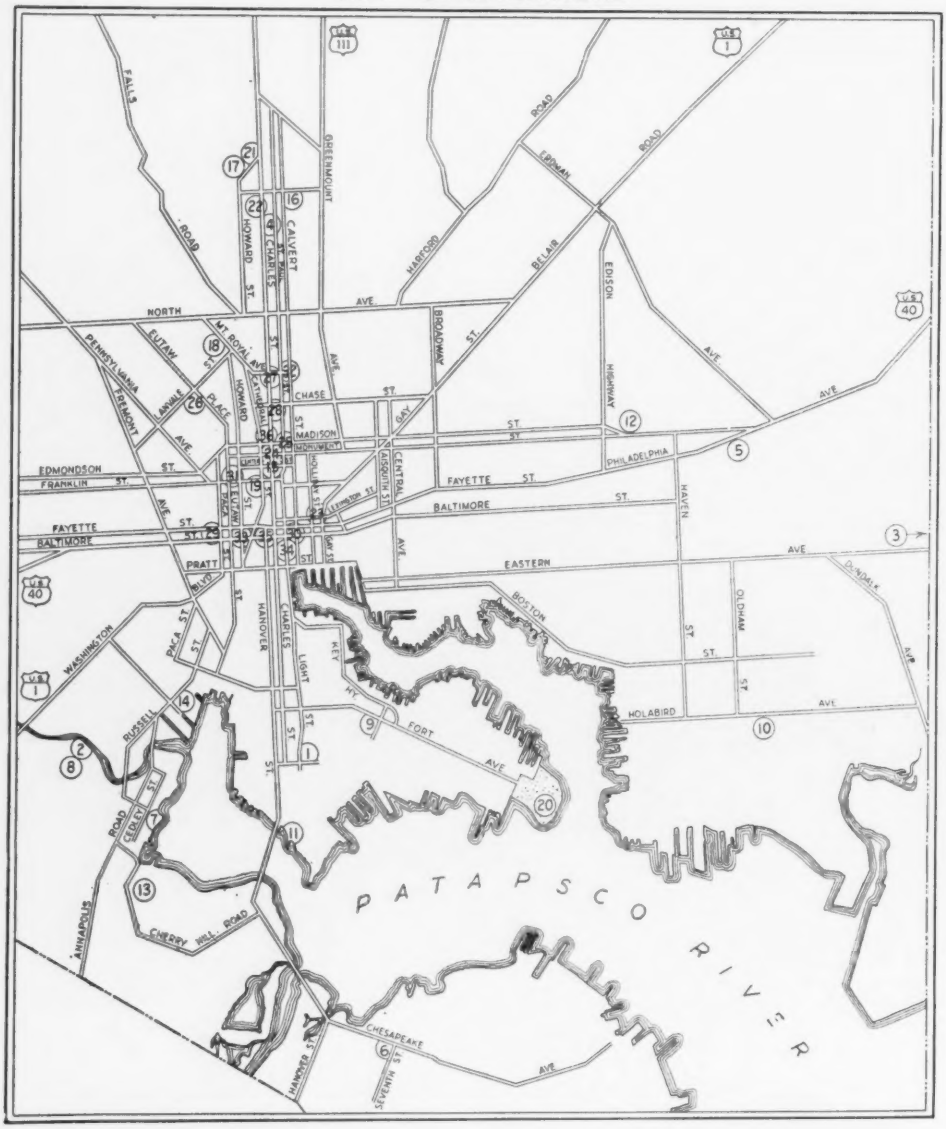
CLAYS
AIR-FLOATED SHREDDED GROUND
FOR EVERY CERAMIC NEED
UNITED CLAY MINES
CORPORATION
TRENTON . . . . NEW JERSEY

MAP OF BALTIMORE



(1) National Enameling and Stamping Co., 1901 Light St.
(2) Baltimore Enamel & Novelty Co., Mt. Winans.
(3) Porcelain Enamel & Mfg. Co., Eastern and Pemco Aves.
(4) Severn Ceramic Studio, 2618 St. Paul St.
(5) Harry C. Weiskittel Co., Inc., 4901 Philadelphia Rd.
(6) General Refractories Co., 701 Chesapeake Ave.
(7) Carr-Lowrey Glass Co., Westport.
(8) Maryland Glass Corp., Mt. Winans.
(9) Buck Glass Co., Fort Ave. and Lawrence St.
(10) American Radiator & Standard Sanitary Corp., 5315 Holabird Ave.
(11) Locke Insulator Corp., Charles and Hanover Sts.
(12) Baltimore Brick Co., 3601 E. Monument St.
(13) Westport Paving Brick Co., Westport.
(14) Swindell Bros., Inc., Bayard and Russell Sts.
(15) Walters Art Gallery, Charles and Centre Sts.
(16) Chen Chao Ming (Chinese Antiques), 339 E. 29th St.
(17) Baltimore Museum of Art, Charles St. and Art Museum Dr.
(18) Maryland Institute, Mt. Royal Ave. and Lanvale St.
(19) Enoch Pratt Free Library, Mulberry and Cathedral Sts.
(20) Fort McHenry and Marine Museum, foot of Fort Ave.
(21) Johns Hopkins University, North Charles and 33rd Sts.
(22) Maryland Academy of Sciences, North Charles and 27th Sts.
(23) Municipal Museum (Peale's), Lexington St. and Holliday.
(24) Washington Monument, Mt. Vernon Place.
(25) Abbey Hotel, St. Paul and Madison Sts.
(26) Altamont Hotel, Eutaw Place and Lanvale St.
(27) Arundel Hotel, Charles St. and Mt. Royal Ave.
(28) Belvedere Hotel, Charles St. at Chase.
(29) Biltmore Hotel, Paca and Fayette Sts.
(30) Emerson Hotel, Baltimore and Calvert Sts.
(31) Congress Hotel, Franklin and Howard Sts.
(32) Mt. Royal Hotel, Mt. Royal Ave. and Calvert St.
(33) New Howard Hotel, Howard and Baltimore Sts.
(34) Southern Hotel, Light and Redwood Sts.
(35) Lord Baltimore Hotel, Baltimore and Hanover Sts.
(36) Stafford Hotel, Charles and Madison Sts.

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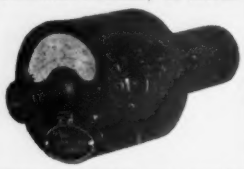

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